

Situation Awareness, Emotions and Time Perception:  
An Investigation of the Effects of Emotions  
on Measures of Situation Awareness, the  
Perception of Time and Decision Making

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SITUATION AWARENESS, EMOTIONS AND TIME PERCEPTION: AN  
INVESTIGATION OF THE EFFECTS OF EMOTIONS ON MEASURES OF  
SITUATION AWARENESS, THE PERCEPTION OF TIME, AND DECISION  
MAKING

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## ABSTRACT

Current theories of Situation Awareness (SA) are based on three broad cognitive processes, that of perception, comprehension and projection. While there are considerable variations on how SA is defined and subsequently modeled (see Endsley 1995, Hancock & Smith 1995 or Edgar & Edgar 2007), most current theories fail to account for the role and influence of emotions on SA. A further shared characteristic of the current models is the lack of integration of SA theories with the ever-increasing knowledge of the functional specializations of different brain areas. This thesis' main aim was to bridge these gaps by integrating current developments from neuroscience and cognitive psychology with perception, learning and decision-making aspects of SA, all within the context of different affective conditions.

The experiments described in this thesis, therefore, share a focus on the emotional effects on the aforementioned cognitive processes as well as detection of possible neural signatures as reflected by Electroencephalography (EEG) recording. The first experiment showed that negative, neutral and positive affective conditions had markedly different effects on the processes of SA. Subsequently, the next three experiments focused on the effects of emotions in a particular aspect of SA, that of decision making, and attempted to isolate the EEG correlates of advantageous and disadvantageous decision-making processes. It was found that about 400 to 300 milliseconds (denoted as SM400) prior to enacting a decision, the EEG recording was able to distinguish between the advantageous and disadvantageous choices. Finally, the last three experiments investigated the mechanisms by which emotions exert their influence on how information is perceived and learned. It was found that negative and positive affective stimuli dilated and contracted the perception of time respectively and that, furthermore, the processing of negative stimuli is based more on long-term

memory as opposed to working memory. The research in this thesis suggests that what kind of SA one person may have is very much affected by emotional processes. This thesis hopes to have contributed to an initial understanding of these processes and stimulate further research on these areas.

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I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in the thesis are those of the author and in no way represent those of the University.

Signed  Date 07/04/2015

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## **Chapter 1 - Current Theory and Application of Situation**

### **Awareness**

#### INTRODUCTION 1.1

*"SA is a simple, easy-to-understand wrong answer"* (Flach 1995). Many organisations, private and public, have invested in the research and development of SA with the aim of improving performance and reducing error. Particular domains, such as the military, aviation (Uhlarik, & Comerford, 2002), accident and emergency services (Gaba, Howard, & Small, 1995) or the management of nuclear plants (Crichton & Flin, 2004) are, understandably, especially sensitive to the subject. Human error in these domains can lead to the loss of human life, potentially in a great scale – see below (Woodhouse & Woodhouse, 1995). A relatively new direction of research in Human Factors and Ergonomics (HFE) has developed out of the attempts to understand and reduce the scope for human error in these high-risk fields. A sub-branch of HFE, which is especially dedicated to understanding safety from the perspective of human-made errors, has been focused on what is called Situation Awareness (SA). The idea of SA research in its basic form simply means understanding how a person becomes aware of their [mainly working] environment so as to avoid costly or dangerous errors. As will be discussed below, several models have been developed in an attempt to operationalize the Situation Awareness (SA) concept in applied settings with some degree of success. In this quest, researchers have tested a variety of paradigms and methods such as questionnaire-based methods; for example Mica Endsley's Three Level Model of SA or Quantitative Analyses of Situation Awareness, which is based on Signal Detection Theory. Mainly based on cognitive psychology, SA incorporates

research from a large number of well known cognitive constructs such as, perception, attention, memory or schemas; the latter plays a central role in many of the SA models.

Though some attempts have been made, psychophysiological measures have not been utilised to any great extent (Wilson 2000). In fact only a handful of studies can be found which directly target the potentiality of psychophysiological methods for contributing to measures of SA (French, Clark, Pomeroy, Seymour, & Clarke 2007). In addition and rather surprisingly, the role of emotions has largely been ignored in SA research.

This thesis represents an attempt to address some of these shortcomings in SA research with a specific focus on the development of theoretical and practical characteristics of SA so that it is integrated with the rapid developments in the understanding of emotional and neurophysiological aspects of human functioning.

This chapter presents a critical review of the currently dominant theories of SA and their application to human performance in high-risk environments; the review is thematic rather than exhaustive. Three different approaches will be evaluated, the three-level model (Endsley, 1995), the perceptual cycle model (Smith & Hancock, 1995), both of which differ among themselves on the degree of importance assigned to either the process or product as indicative of Situation Awareness (Stanton, Chambers & Piggott 2001). Finally, Quantitative Analysis of Situation Awareness (QASA), which is based on Signal Detection theory (Edgar & Edgar 2007), will be evaluated against the previous two theories. QASA is currently leading the field in developing neural activation measures based on electroencephalography (EEG) as indicators of SA – both of which are key elements to this thesis. It will be argued that the addition of psychophysiological measurements to the current measures of SA may

help drive new lines of inquiry through which we can further develop understanding of SA. Developed by Dr. Graham Edgar on behalf of BAE systems, QASA is a relatively new and promising arrival in the field. Further inquiry into this approach is the starting platform of this PhD thesis hence QASA will be particularly closely inspected.

## 1.2 BACKGROUND INTO THE CONCEPT OF SA

Put simply, SA is the capability to keep, record, and represent the changes in the environment as an accurate mental model. Typically SA is important when a human operator has to manage several processes, often simultaneously, to ensure good performance (Endsley, 1995). A familiar example would be drivers who must at the same time that they scan the road, maintain and adjust the correct pressure on clutch and gas pedals, be ready to stop or communicate their movement intentions to other drivers via signals and so on. Assuming they possess the right skills to perform each of the required actions, they have got good SA if when a specific performance or behaviour is required, a specific skill, (i.e. emergency braking) is triggered as a result of an accurate mental image of the current situation.

The concept of SA is particularly relevant to industries that involve high degrees of risk, such as the military aviation industry (Jensen 1997), battlefield (Kass, Herschler, & Companion, 1991) or medical procedures (Gaba, Howard, & Small, 1995). In the literature, the loss of SA is linked to many accidents with a large proportion involving the loss of human life. In a review of Controlled Flight into Terrain (CFIT) aviation accidents, Woodhouse & Woodhouse (1995) reported that 74% of aviation accidents, or about 5000 deaths from 1978 to 1992, could be attributed to loss of SA as opposed to impaired proficiency of skill (Gronlund, Ohrt,

Dougherty, Perry, & Manning, 1998). Likewise, Hartel, Smith & Prince (1991) report that poor SA was a causal factor in 200 aircraft accidents.

More recently, a renewed interest on SA has followed the rapid expansion of information technology and increased automation in typically human controlled processes. There are increasing concerns regarding the new demands imposed on the attentional and monitoring resources of operators; having several options for completing the same task is not necessarily always helpful. Sarter & Woods (1995) point out that the increase in the number of functions, options and automation means that the human operator has to monitor the systems to a much greater degree than before. The ever increasing and differing sets of options associated with each systems' mode of operation, Sarter and Woods argue, creates new attentional demands. An operator must know which mode the system is on, how to track the operations of the current mode, how to shift if needed to another mode of operation, and how it will behave next. The increase in flexibility, though appearing advantageous at first glance, may exceed human monitoring capabilities (Stanton, et al., 2001). Furthermore, it may result in adding to the cognitive workload especially at those critical times when an effective support system is most needed (Sarter & Woods, 1995). A pilot's statement describes this new problem very clearly: "*With old cockpits the workload was high but you were always aware of what's going on.*" (Adams, Tenney & Pew, 1995; Stanton et al., 2001).

### 1.3 DEFINITIONS OF SITUATION AWARENESS

Although a fuzzy concept which is hard to define, the understanding of SA is often assumed as though it is self-evident (Adams et al., 1995). In reality no agreement exists on a single definition and a large and varied number of definitions and

measurements are still in circulation (Rousseau, Trembley & Bretton, 2004). In a special issue on SA in Human Factors (Volume 37, No. 1) all articles, nine in total, define SA in different terms (Baxter & Bass, 1998). Nevertheless, Stanton et al., (2001) distinguish three that have dominated the literature over the years:

1. *“Situational awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and a projection of their status in the near future”* (Endsley, 1988).
2. *“Situational awareness is the conscious dynamic reflection on the situation by an individual. It provides dynamic orientation to the situation, the opportunity to reflect the past, present and future, but the potential features of the situation. The dynamic reflection contains logical-conceptual, imaginative, conscious and unconscious components, which enables individuals to develop mental models of external events”* (Bedney & Meister, 1999).
3. *“Situational awareness is the invariant in the agent-environment system that generates the momentary knowledge and behaviour required to attain the goals specified by an arbiter of performance in the environment”* (Smith & Hancock, 1995).

Stanton et al, (2001) and Salmon, Stanton, Walker & Green (2006) argue that the main difference between these three definitions is whether they consider SA to be synonymous with the cognitive processes engaged in creating it, or as a separate product, the creation and the update of which those processes contribute towards. Endsley’s model of SA (first definition above) is a product-based approach whereby SA is seen as separate from the processes that contribute to it; the latter can be different in different people or circumstances, Endsley argues (Endsley 1995a). The processes used to achieve SA are regarded as not exclusively related to a specific skill

or technical expertise (O'Brien & Hare 2007) but nevertheless are regarded as important to ensure good performance (Wiener, Kanki, & Helmreich 1993; Helmreich, Merritt & Wilhelm, 1999).

On the other hand, the Smith & Hancock's (1995) model of SA, which is an extension of Neisser's (1976) perceptual cycle model (Figure 1.1), places the emphasis on the interaction between the individual and environment.

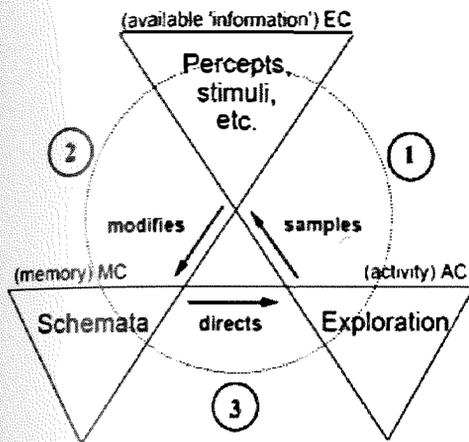
In accordance with Neisser's earlier model, Smith and Hancock suggest that interaction is driven by continuous feedback loops between (external) environmental stimuli and (internal) schemata whereby environmental stimuli help activate or trigger schemas which, in turn, drive further exploration that, again, activate and modify schemas and so on in a continuous cycle (Stanton, Salmon, Walker, Baber & Jenkins 2005); SA, it is argued, results from that interaction.

Similar to Smith and Hancock's model, the Quantitative Analyses of Situation Awareness (QASA) method emphasizes the processes that are used in achieving SA. There is, however, a clear focus on the individual's early cognitive processing tendencies. The QASA model suggests that early information bias (IB) in information processing stages restricts the information that is 'passed on' and thus the kind of SA an operator can have (see sections 1.6, 1.6.1 and 1.6.2 below).

An operator with a bias toward stringent filtering of information will have SA based on a restricted range of information whereas, conversely, an operator with lax bias will have SA based on a wider range of available information (Edgar & Edgar, 2007). Each type of SA has its own characteristics, which may be advantageous in some situations while being disadvantageous at others. The important departure from earlier models is that, conceptually, QASA moves away from good and bad SA emphasizing instead a relationship between different types of situations with different

types of SA. This approach invites researchers to explore the characteristics that emerge from the relationship between specific facets of a situation (i.e. the urgency, time available, personality traits) and different types of SA (based on a larger information base or a more restricted one).

### Neisser's perceptual cycle (1976)



### Smith & Hancock perceptual cycle (1995)

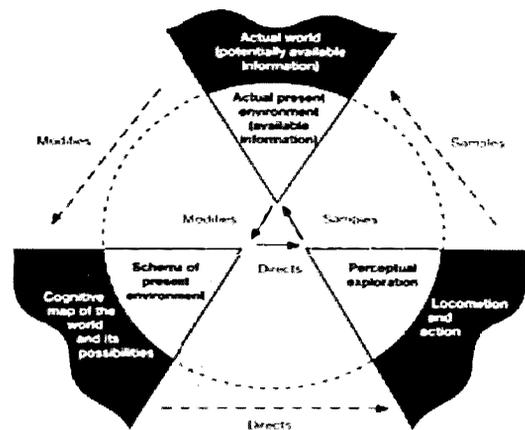


Figure 1.1: Neisser v Smith and Hancock Models. Both Neisser and Smith and Hancock models share the cyclical nature and the base operations: samples, modifies, directs. Smith and Hancock's model provides more fine-grained definitions of Percepts, Schemata and Exploration stages.

In the next section all three models of SA will be critically evaluated starting with the Endsley's model of SA.

#### 1.4 THE THREE LEVEL MODEL OF SA

Endsley (1995) proposes a three level model of SA which she defines as: *the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future* (Endsley, 1995). This definition is further deconstructed into three linear levels, that of Perception, Comprehension and Projection.

*Perception:* This is seen as the most fundamental level of SA and the one most dependent on the domain of operation. This level requires a mental representation of the environmental elements along with their status, attributes and dynamics. A descriptive example is that of a tactical commander who would need to know “*location, type, number, capabilities, and dynamics of all enemy and friendly forces in a given area and their relationship to other points of reference*” (Endsley, 1995). As mentioned previously, the elements likely to be important for achieving perceptual level SA depend on the operational domain within which SA is required. The next two levels that follow are more generic in that they are regarded as not intrinsically linked to a specific domain, in other words not dependent on a specific environment.

*Comprehension:* Using reading as an analogy, Endsley states that the difference between perceptual and comprehension level is “*analogous to having a high level of reading comprehension as compared to just reading words*” (Endsley, 2000). In other words, the meaning of a situation is what the second level of SA refers to. Further on, Endsley argues that this meaning should be considered in term of subjective interpretation (awareness) and as objective significance (situation) and the meaning must be in line with operator goals. For example, when a soldier observes the movements of enemy forces in some particular formation and within a certain proximity to his post, that should give him/her some indication of their intent and objectives as well as what that means in relation to their goals. So, besides being aware of the relevant elements, some interpretation or narrative that binds those elements together is the condition for level 2 SA.

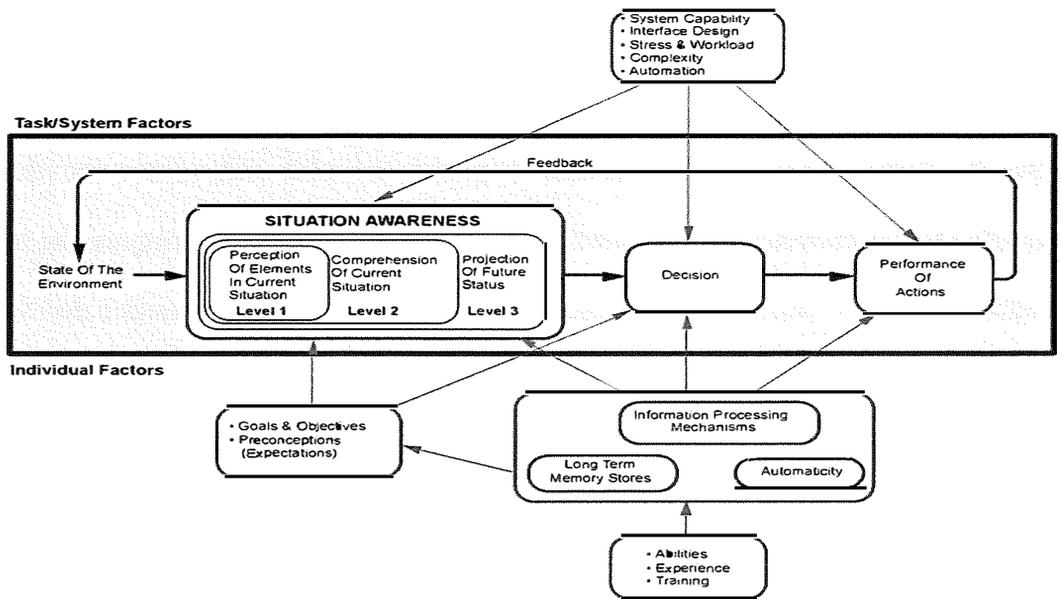
*Projection:* The term projection is not used here in the sense of planning an outcome but rather anticipating one. This is seen as the top level SA and often a mark of the expert (Endsley, 2000). Projection, being the most advanced level of SA within

this model, requires good knowledge of both levels of SA, perception (the elements involved) and comprehension (the understanding of their meaning and the relationship between them). For example, the accurate knowledge of enemy and friendly forces, landscape details, the equipment available and so on and the comprehensive understanding of their relations would allow a military commander to project with some degree of confidence the most likely future states and enabling guided decision making and contingency planning. Accurate anticipation means that a decision maker is efficient in his planning and will increase the effectiveness of the allocation of resources, cognitive and otherwise, and more importantly reduce costly errors (Endsley, 2004).

Endsley argues that as well as separate from the processes that support it, SA should also be considered as a separate construct from other processes that may influence it, such as attention, working memory, workload and stress. The processes that support SA are organised collectively under the term “*Situation Assessment*” and, Endsley argues, they can be different in different people though how they may differ is not specified in great detail.

More importantly, Endsley argues, SA should be seen as separate from either performance or decision making (Figure 1.2), suggesting that a person may have great SA but performance may be poor due to lack of training or poor tactics; whereas decision makers may arrive at the right decisions even if the SA is lacking.

Consistent with Endsley’s model, McGuinness & Foy (2000) have proposed to add a fourth level to Endsley’s model, Resolution, which provides awareness of the best path to follow towards a desired outcome. Resolution is the capability to draw a single course of action from a subset of available actions, establishing a link between knowing what is going on and decision-making.



*Figure 1.2: Endsley's Three Level SA Model.* As can be seen, Endsley's model is a typical box and arrow diagram. The mechanisms of SA are perceived as separate from decision-making, goals and objectives and information processing stores.

It is important to highlight at this point that SA appears to be treated as another information processing box. Even though McGuinness and Foy rightly draw attention to the idea that SA may benefit from a clear integration with decision-making, their approach only amounts to simply adding another information processing box. Flach (1995) is critical of Endsley view of SA as a separate construct stating that, as regarded by Endsley, SA amounts to just adding yet another box in the information processing diagrams somewhere after attention and before decision making (Figure 1.2). Evidence will be considered below which suggests that the box and arrow approach may be incompatible with the emerging picture of the functioning of the brain; evidence emerging from brain imaging indicates that the neuronal structures operate in a much more fuzzy way than the box and arrow approach suggests. There are further issues with Endsley's approach, which will be discussed below (sections 1.4.2 to 1.4.2.5) but its application will be considered first. Based on

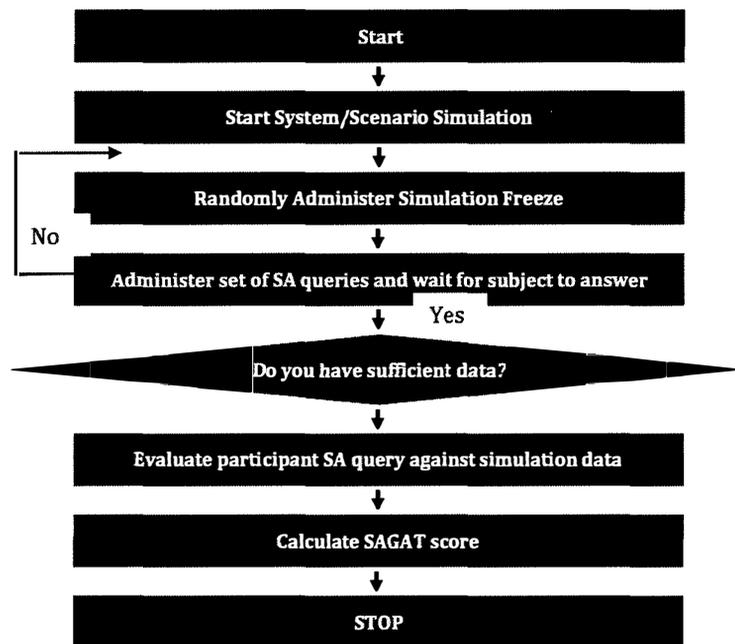
her three level definition, Endsley (1995, 2000) has developed a measure of SA known as the Situation Awareness Global Assessment Technique (SAGAT). As will be discussed, the success of SAGAT is largely dependent on the degree of accuracy and the depth of the description of a situation.

#### *1.4.1 The Situation Awareness Global Assessment Technique*

The Situation Awareness Global Assessment Technique (SAGAT) is the principal measuring tool that has emerged from Endsley's model of SA and is based on the freeze-probe technique (Stanton et al., 2005). Individuals assessed are presented with a number of questions which are designed to target knowledge at the three levels of SA (Endsley 1995b), level 1 SA (perception of the elements), level 2 SA (comprehension of their meaning) and level 3 SA (projection of their future status). The SAGAT method was originally designed to assess the SA of pilots in the military aviation domain, and variations of it were adopted for other uses such as SAGAT-Tracon, which is a specific air traffic control version or SACRI (situation awareness control room inventory), designed to assess the SA of a control room operator (Stanton et al., 2005).

The SAGAT assessment method is usually administered online and is based on some form of simulation of the situation under analysis. At various random points, the performance on the task is 'frozen' and a number of questions are presented to the participants, querying for information at each of the three levels of SA at that point in the task (figure 1.3). An example given by Endsley (1995b) describes an administration of SA in the context of military aviation. Examples of level 1 SA question include queries about aircraft location, destination, altitude, weapons or fuel level quantity and so on; level 2 SA queries assess information about impact of

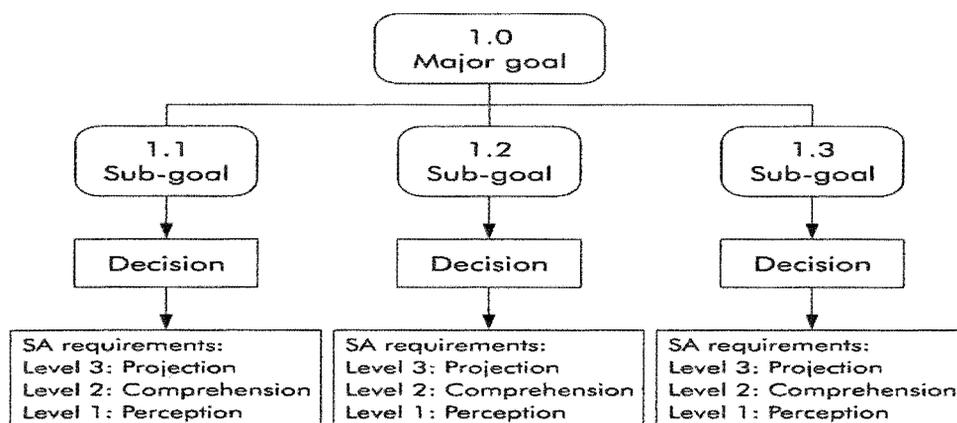
system degrades, tactical status of threatening aircraft, availability of fuel in terms of time and distance whereas level 3 SA queries are themed around predictions of immediate future such as intended tactics and actions of the threatening aircraft or firing positions. At the end of the task, a SAGAT score is calculated which also factors in a measure of the time elapsed during the ‘freeze’ time when participants are answering the SAGAT questions.



*Figure 1.3: The SAGAT Flowchart.* The flowchart depicts the main steps and the sequence of a typical SAGAT administration procedure (Stanton et al., 2005, pg. 232).

A major if not the most important aspect of the SAGAT technique is the generation of questions addressing all three levels of SA. Endsley (2000) has suggested goal directed task analysis method whereby the task under question is deconstructed into major goals and sub-goals (Figure 1.4). A wide range of cognitive engineering procedures are used to extract the questions. Input from experts, observations, verbal protocols, analysis of written material and questionnaires are also factored in. Endsley admits that it is a complex process, which can take up to a year to

accomplish (Endsley 2000). Endsley notes, however, that once a full analysis is carried out, SAGAT can be used repeatedly as long as there are no major changes of operator procedures or objectives.



*Figure 1.4: SAGAT Method of Deconstructing Goals.* Major goals are deconstructed into minor/sub goals. Each sub-goal is broken down into a series of decisions necessary for achieving each sub-goal. The SA information at each level of analysis, Perception, Comprehension and Projection, are then identified with regard to the decisions; the SAGAT questions are derived from this information (Source: Wright, Taekman & Endsley 2004).

#### 1.4.2 Application Limitations and Validity of Endsley's Model of SA

A major limitation of the SAGAT technique is that the assessed information important to a situation is locked to a specific domain (Rousseau et al., 2004; Endsley, 1995). For example, the SA of a soldier in a battlefield is necessarily different when compared to that of a general working on the strategic aspects of a battle and further different still when compared to someone working on a nuclear plant's safety procedures. In each case the maintenance of SA requires different skills, it reflects different aspects of the environment and serves different goals. This limits the application of each SAGAT analysis to a very specific domain, which apart from the inefficiency and the added cost to its application, more importantly also restricts the

attempts at validating its results to that specific domain. The domain specificity of each SAGAT application makes its claims difficult or impossible to verify independently. Furthermore, SAGAT is built by the amalgamated contributions of a wide range of processes, which lack a specific psychological profile and appear somewhat put together in an ad-hoc style. Endsley explains (Endsley, 2000) that SAGAT is built over many months and sometimes years drawing contributions of domain-specific experts, psychology experts, observations by both categories, analysis of documents and other.

There are further ambiguities that add to the difficulty and cost of repeating the procedures that create a SAGAT-type analysis. For example, how was the expertise and competency of the contributing experts assessed? Obviously not all experts are of the same mental and professional capacity. Also, how exactly were the analysis of the materials and protocols carried out? How can a researcher and assisting experts creating a domain specific SAGAT make sure that their observations are consistent with the ones made by Endsley? In other words, much more detail is needed about SAGAT procedures if its claims are to be independently verified. If not, any findings not in accordance with the ones reported by Endsley can be easily dismissed as a difference on one or many of the processes involved in creating that specific SAGAT questionnaire. While its application may be useful to a business or organization, from a research perspective more procedural details are needed to assess its validity. The fact that it is widely used offers little scientific comfort: *“The work of science has nothing whatever to do with consensus. Consensus is the business of politics. Science, on the contrary, requires only one investigator who happens to be right. In science, consensus is irrelevant. What is relevant is reproducible results. The*

*greatest scientists in history are great precisely because they broke with the consensus.”* (Crichton 2003).

Dekker (2001) expresses a similar concern with the whole field of SA research: *“Falsifiability means the investigator has to leave a trace that others can follow. In human factors it is not uncommon to make the shift from context-specific to concept-dependent in one big leap (e.g. “this underestimate of the closing rate signifies a loss of situation awareness”); which produces conclusions that no one else can verify.”*

Research and theory on SA has been dismissed as abracadabra (Dekker & Woods 2002) and denigrated to folk psychology (Dekker & Hollnagel 2004), therefore bringing greater scientific clarity to its measuring procedures will be of benefit to everyone and lend scientific credibility to the field.

#### *1.4.2.1 Problems of Causality, Inference and the Resurrection of the Homunculus.*

Flach (1995) was the first to raise the concern about the circular reasoning often found in SA literature. In a stern critical analysis of SA models, especially Endsley’s, he acknowledges that SA denotes a useful research construct but Flach alerts to the danger of falling into circular logic. If SA is assigned causality, in other words considered the cause of some effect, an error or decrease or increase in performance can be considered both to arise from poor SA and to contribute to it (see for example Hartel et al., 1991 above). Statements of the type “a loss of SA caused some human error”, widely prevalent in SA literature, lead to circular reasoning of the type: *“We know SA was lost because the human made an error – why the human made an error, because SA was lost”* (Flach, 1995). Flach expressed concern about the easily

misunderstood nature of SA: *'As a causal explanation, SA is a simple, easy-to-understand wrong answer that, in the end, will be an obstacle to research.'* Endsley (1995a) also makes the same mistake while arguing for the limited capacity of SA. She says that improved SA on some elements via involvement of attention may mean loss of SA on some other elements (Endsley, 1995, pg. 41). If we denote the two sets of hypothetical elements in question with A and B, how then do we know the SA for A was lost, because SA for B increased? Why did SA for B increase, because SA for A was lost! Furthermore, assigning a causal role to SA necessitates the resurrection of the all-knowing Homunculus in the brain. In the vast complexity of the environment, who decides which parts of it make the situation? The causal role assigned to SA in this case implicitly assumes a homunculus that evaluates information and makes predictions. Logically, this is an indefensible position.

#### *1.4.2.2 Preserving the Dynamic Link Between the Situation and Awareness*

SA has often been labeled as an ill-defined concept made up from a multitude of other ill-defined concepts (Sarter & Woods 1991). Additionally, the idea of having a static and bounded SA that, furthermore, is strategically ignored seems highly unlikely. If one makes a bad action or decision then surely it must be factored in as part of the poor overall SA arsenal: e.g., if SA says that when the enemy is in position X then you must do Y (when in fact you should do Z), then surely this is part of a poor overall SA schema? Moreover, people in the same settings can have equally valid but radically different explanations and models to capture it; it is known that all the elements of perception and other cognitive processes are strongly context bound (Dekker & Lutzhoft 2004).

The fluidity and inconstancy of the world has been noted as long ago as pre-Socratic times. Heraclitus said “*you cannot step into the same river twice*”, an insight expressed more accurately later on by Cratylus ‘*you cannot step into the same river once*’ both describing a world which is always fluidly moving between the past and the future. In psychology, this fluidity of the world is often denoted by the term ‘*dynamic environment*’ (Osman & Speekenbrink, 2011). Dynamic environment denotes a state of affairs in which the environmental states are in a continuous change. While a snapshot within this series of successive environmental states may be correctly interpreted by an operator, by the time that an action is taken, it may well be that the situation has changed so that that action has become obsolete, less effective or even dead wrong. Therefore SA cannot be referred to as a state or a product and yet maintain the link between SA and a dynamically changing environment. If the environment is in continuous change, so should SA.

Likewise, Patric & James (2004) emphasize the importance of preserving the dynamic link between situation and its awareness: “*As a phenomenon (SA) it is necessary to examine the relationship between the dynamically changing situation and a person’s understanding or awareness of it. The two sides of this equation are inseparable [...] Useful generalizations concerning SA will only emerge when analyses preserve the link between characteristics of a particular situation and a person’s awareness of it.*” (pg. 67). Similarly, Smith & Hancock (1995) have argued that any measure of SA is rendered impossible if it is not tied in closely to performance.

Finally, evidence emerging from neuroscience is supporting a brain/mind that functions in a much more fuzzy and integrated way, which is at odds with SA as a box approach. For example, Bar (2003) and Bar, Kassam, Ghuman, Boshyan, et al.,

(2006) report that the prefrontal cortex (PFC) facilitates the top-down processing of perceptual information and integrates it with the bottom-up processing, suggesting therefore that memory, and perhaps schemas, are influenced by and influence perceptual processing in a cyclical fashion. The perceptual information, according to Bar, is coarsely and quickly passed through to the PFC via occipital cortex, which then projects back to the temporal cortex the most likely initial guess which further on, re-enters or feeds back to the bottom-up processes of recognition. This has the effect of limiting the number of interpretations for the stimulus and therefore speeding up recognition; a mechanism, which might be crucial under conditions of time pressure. Bar et al., (2006) conducted a study using both Magnetoencephalography (MEG) and functional Magnetic Resonance Imaging (fMRI) while participants completed a behavioural task that facilitated object recognition with repeated trials. They found that activity in the left orbitofrontal cortex preceded activity on the areas that are known to facilitate object recognition, the temporal cortex.

Luu, Geyer, Fidopiastis, Campbell, Wheeler, Cohn & Tucker et.al., (2010) also found support for this view. Luu et al., (2010) argued that perceptual processing must be further organised into meaningful concepts, which reflect the perceptions from which they arise. Using a modified version of the Waterloo Gestalt Closure Task while recording the participants' brain activity with Dense Array EEG (dEEG), Luu and colleagues found that the activity in medial orbital frontal electrical responses (about 250 ms post stimulus) was associated with intuitive judgments. At 150 ms post stimulus presentation, activity in the temporal-parietal-occipital (TPO) predicted activity in the mOFC, whereas at ~300 ms, 150 ms later, TPO was influenced by mOFC. According to these findings, Endsley's model describes a psychological

function, which appears to be ungrounded since in this model, perception, comprehension and anticipation are somewhat linearly organised.

#### *1.4.4.3 The Problem of Disengagement (Freeze Technique)*

The two sides of the equation crucial to SA are the environment and the person embedded in it. SAGAT breaks this link in two counts: 1) its measures require that participants disengage with the task while the questions about their SA are answered (figure 1.2, above), and 2) this means that SAGAT data are calculated based on the reconstructive memory which may or may not reflect the SA at the time and is likely to invoke instead what a participant reasons in retrospect about what should have been known. In which case, the SAGAT indication of good SA may actually indicate another measure on another capacity. Participants with longer experience and training may be in a better position to infer the correct answers even if the SA at the time may have been no different from others.

Endsley (1995; 2000) draws attention to the differences between experts and novices as a demonstration of SAGAT's power to show the difference between good SA (experts) and poor SA (novices). Differences in SAGAT measures between experts and novices could also be interpreted as SAGAT's power to show the differences in training and experience rather than differences in SA. Also, the involvement of experts in the process of deriving the questions for SAGAT may also go some way into explaining why experts generally score better in SAGAT type scenarios and questionnaires.

Another issue has been with regard to the degree of the interference and deterioration on performance that "freezing" an ongoing task may cause. Aware of the problem, Endsley has carried out a series of experiments to test the effects of 'freezing' on performance. She reports several studies, including many that she

orchestrated herself, which did not find a significant effect of the ‘freeze’ aspect of SAGAT on participants’ performance (Endsley 2000). However, McGowan & Banbury (2004) report that ‘freezing’ or interrupting does indeed affect participant performance. In a driving hazard perception test, McGowan & Banbury (2004) found participants’ hazard perception scores decreased when participants were interrupted. They suggested that the previous studies did not find interruption effects on performance because they did not take into account reorientation effects (questions about a situation highlight to the participant which aspects of the task are relevant to the questions), which compensate for the ‘freeze’ or interruption effects on the SAGAT. This would confound the performance measure, which in real terms may actually deteriorate. McGowan & Banbury (2004) urge caution when interpreting interruption based measures, such as SAGAT, because the results of such measures may be dependent on the construct used to generate the queries leading, again, to a circular reasoning approach.

#### *1.4.2.4 Normative versus First Person Perspectives*

Dekker & Lutzhoft (2004) have criticized Endsley’s approach from the standpoint of the normative against first person perspectives and have highlighted some issues which arise when comparing an arbitrary idea about what should have been known with what was actually known as a way of measuring SA. To have a valid measure of SA there should be a way to understand why it made sense for people to think and act in the way they did at that specific time and place. In retrospect, what can appear as an appalling loss of SA can be just a normal working experience to the individual who is immersed in the actual situation as it is happening. The most important question is, how is it possible that what can look like as an unbelievable loss of SA from a

retrospective observer's point of view, appeared completely reasonable from the insider's perspective? There is no indication that this issue is sufficiently recognised in Endsley's model of SA.

The 'picture' or model formed with the view to measure what should have been known or should be known are usually derived in conditions where 1) the performance of detailed analyses are possible and 2) analyses are performed at leisure, quite contrary to the often time-pressured decision making conditions that are encountered in real life. This is comparable to studying the cognitive processes of people driving a golf cart in order to understand the cognitive processes involved when driving a formula one car. Even if both behaviours involve a similar set of skills the environments in which they operate are radically different. A derivative of this perspective is a seductive but misleading frame of reference by which a normative rendering of reality is artificially imposed on the immediate reality within which an individual actually operates. In the immediate reality, the individual is invariably embedded in the immediate context, which dictates what elements of the environment are processed (Dekker & Lutzhoft 2004). Therefore, by definition, their SA assessment is incomplete.

#### *1.4.2.5 Summary of Critique on Endsley's Model*

As already acknowledged, Endsley's model has been, and continues to be, the most widely used SA model in human factors research. There are a large number of studies that have confirmed its findings and a further large number of studies that have attempted to validate various aspects of Endsley's model. However, there are also many criticisms (some of which fundamental) to this model and the assumptions that it makes. The SA as a box approach, separate from decision making and attention,

circular reasoning and the difficulty of testing its claims are some of the issues that have been identified by researchers. Especially the difficulty of verifying the model's claims by being able to replicate exactly its supporting studies is a major obstacle which hinders rigorous scientific examination of the work validating this model.

Next, the perceptual cycle model is considered.

### 1.5 SMITH & HANCOCK'S PERCEPTUAL CYCLE MODEL

In this section the main aspects of the perceptual cycle model will be described and then contrasted against an earlier model, Supervisory Attentional System (SAS) proposed by Norman & Shallice (1982). It will be argued that though both models share common elements, the perceptual cycle model represents a step back not forward when compared to SAS even though the latter was proposed years earlier.

In the perceptual cycle model, Smith & Hancock (1995) suggest that SA should be seen as residing in the interaction between the individual and their environment and not in either of them. Furthermore, Smith & Hancock suggested that SA should not be regarded as either a product or a process but rather as a combination of both; in other words SA should be seen as a product, which is continually shifting and updating. In this framework of SA, the emphasis is placed on the dynamic interaction between environment and individual and a further emphasis is also placed on the role of the internal models, which, similar to the role of schemas in Neisser's model, drive and are driven by the external element of situations. In a similar but more general way, the role of the internally held mental models in the Smith & Hancock perceptual cycle model of SA are to anticipate and feedback into the development of the situation which in turn drives the exploration process which may validate the expectations or, if not, modify them accordingly. Both Neisser (1976) and

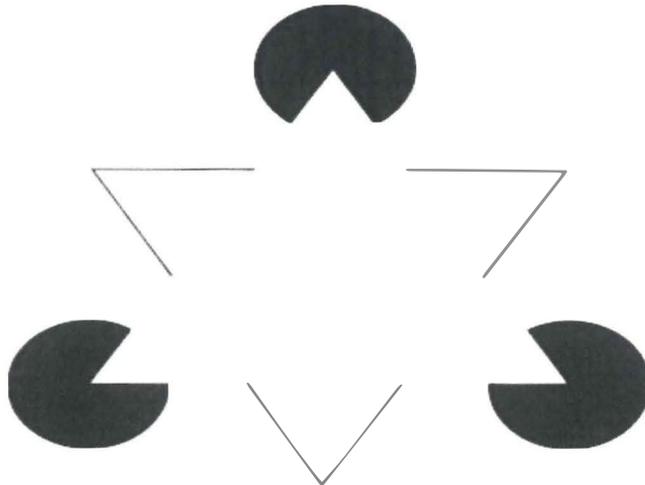
Smith & Hancock (1995) describe perception as an active adaptive process. In contrast to Endsley's linear model, a central aspect to this approach is its cyclical nature. The schemas are the active knowledge structures, which direct the exploration of perceptual processes and feedback their interpretation to the perceptual processes to further guide their exploration; the content and structure of schemas are the driving force in this model. Their function is to provide a link between prior experience and current situation, the combination of the two creating the frame of reference for anticipations.

Suggesting that SA is a subset of the overall content in working memory, nevertheless, Smith and Hancock suggest that it is an "*externally directed consciousness*" which indicates that "*the goal of the behaviour that SA directs must reside in the task environment rather than in the agent's head*" (Smith & Hancock, 1995) therefore the SA is linked to the dynamics of the environment rather than to an internal model as the Endsley's model suggests. The measurements of SA are made possible via the specification of the goals within the task environment which are restricted both by environmental and task constraints, and operator's active knowledge and experience or as Adams et al., put it (1995, p.90) "*the perceiver's active schema*".

### *1.5.1 A Brief Description of the Concept of "Schemas"*

Since schemas feature quite heavily in both Endsley's model and this one, a brief description of the main features of this concept is useful at this point. One definition of schema is: "*Schemata can represent knowledge at all levels-from ideologies and cultural truths to knowledge about the meaning of a particular word, to knowledge about what patterns of excitations are associated with what letters of the alphabet. We have schemata to represent all levels of our experience, at all levels of abstraction.*"

*Finally, our schemata are our knowledge. All of our generic knowledge is embedded in schemata.*” (Rumelhart, 1980). Schema can integrate their own inherent schema expectancies with stored perceptual details that actually occurred (Miller & Gazzaniga, 1998); often, the expectancies of the schemas will lead to vivid recollections of details or events that did not happen which may match in intensity those that actually did happen. An elegant example of schema and their influence on perception and memory is cited by Miller & Gazzaniga (1998) who reported on a classical experiment by Brewer & Treyns (1981). Graduate students who had waited in a “graduate student’s office” were unexpectedly asked to recall what was in the office. Students (falsely) recalled to have seen items like books and so on which one would expect in a student’s office. Furthermore, at a perceptual level the effect of schemas may be illustrated by various illusions; a simple demonstration is given in figure 1.5 below; although there is no triangle anywhere in that figure, triangles are clearly perceived.



*Figure 1.5: Kanizsa’ triangle (1995).* Kanizsa’ triangle demonstrates the effect of schemas on perception; The information contained in the photo (bottom up processing) triggers the ‘triangle’ schema which then effects perception (top down processing) resulting in triangles being ‘seen’ even though there is no triangle.

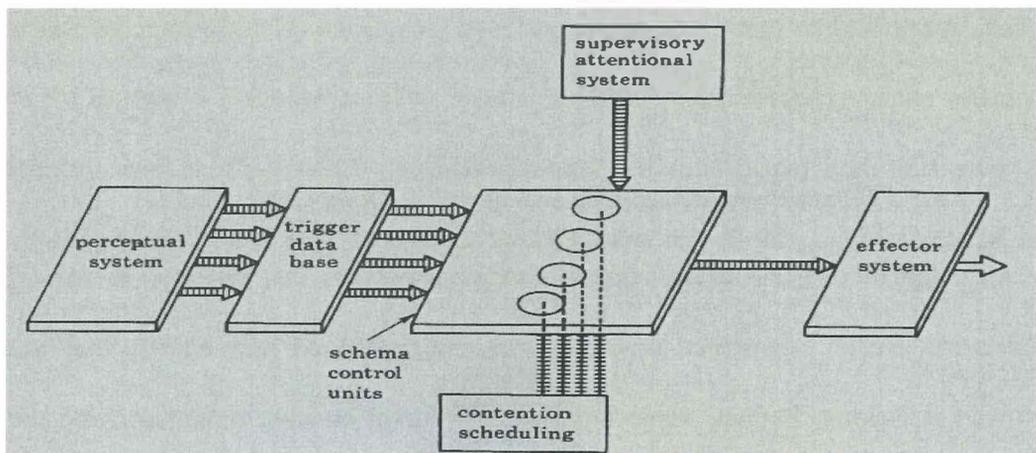
Schemas, therefore, represent the ability of the mind to create an abstraction of related patterns out of the streams of information, store them and recognize them later on. They can be considered as the brain's solution for handling vast amounts of information. The relevance of schema theory to the SA theories is self-evident. Evidence from studies with schemas suggests, however, that they operate largely in an automatic fashion below the level of conscious awareness and are involuntary (Norman & Shallice, 2000). All of those properties of schemas are incompatible with the view of SA as an essentially conscious structure (Endsley 1995a), and yet schemas are placed at the center of the SA models of both, Endsley (1995) and Smith & Hancock (1995).

#### *1.5.1.1 Comparison Between the SAS and Perceptual Cycle Models*

Even though there is no disagreement among researchers that schemas or mental models are a useful construct in SA, a clear explanation on how exactly they are involved is lacking. Perhaps some light can be thrown on their operation from the Norman & Shallice's Supervisory Attentional System (SAS) model (2000). SAS is described as having "*access to a representation of the environment and of the organism's intentions and cognitive capacities. It is held to operate not by directly controlling behaviour, but by modulating the lower level [resources] by activating or inhibiting particular schemata. It would be involved in the genesis of willed actions and required in situations where the routine selection of actions was unsatisfactory for instance, in dealing with novelty, in decision making, in overcoming temptation, or in dealing with danger.*" (Shallice, 1988, p335.)

The SAS is highly related to the central executive component in the working memory model (Baddeley & Hitch 1974), to the concept of intention as used in Bratman

(1987), and to awareness on ‘global workspace theory’ (Baars, 1988). The SAS model is principally based on studies with people with brain damage. Within the SAS model, Norman & Shallice (1986) suggest that people with damage in the prefrontal cortex and the cingulate structures may have a compromised SAS functioning but intact horizontal thread functioning (contention scheduling) which is why they are able to carry out simple tasks but are impaired in complex tasks. Shallice (1982) reported a trend that people with damage in the frontal lobes were significantly impaired when performing complex tasks while at the same time they were able to perform simple tasks normally.



*Figure 1.6: Norman and Shallice Supervisor Attentional System Model (1980). This is a simplified SAS model representing the flow of information.*

Evidence suggests that many different brain regions distributed over the cortex may be involved in SAS-type control operations (Garavan, Ross, Li & Stein, 2000). Furthermore, the work from Damasio and colleagues in the late 1980s, early 1990s highlighted the importance of emotions (Damasio, 1994) in these processes, an idea that is not considered in either Endsley’s or Smith and Hancock’s models.

There are two main assumptions that underpin the SAS model which bear particular relevance to SA, the automatic (schema) and the controlled or willed

processing (SAS) of stimuli (as shown in figure 1.6). Automatic processes require little or no mental effort, no awareness or intention, do not interfere with other mental processes, are fast and sometimes unavoidable (Eysenck & Keane, 1995; Wood, 1983, Pg. 38). Automatic processes can be acquired by training (riding a bicycle for example) and have clear benefits (increasing performance speed, preserving mental effort for other tasks), but they also introduce a cost. Since automatic processes are generally not available to consciousness, they are less flexible and, more importantly, they do not impinge upon monitoring resources except at points when the processes fail due to some change on the prevailing circumstances. If such failures are not detected then 'action slips' may occur (Norman, 1981; Botvinick & Bylsma, 2005). When problems are detected, attention is engaged along with other cognitive resources in order to make sense of the new information (Hawkins & Blakeslee, 2004); deliberate control at this point is necessary.

Norman and Shallice (1980) suggest that deliberate or controlled actions are particularly necessary for:

- Tasks that involve Planning or Decision Making
- Troubleshooting
- Ill learned or novel sequences of action
- Tasks that are dangerous or technically difficult
- If a task requires overcoming of strong habitual response or resisting temptation

In all five situations outlined above, the use of uncontrolled automatic processing may lead to error; therefore conscious and effortful processing is also required (Norman & Shallice, 1980). Arguably, the five outlined situations also represent the totality of the situations about which SA is sought. Two complementary

processes are outlined, the first for handling simple and well learned acts and the second for the conscious attentional control which modulates performance. These processes exert their influence via a third mechanism named contention scheduling. Contention scheduling, which operates at the automatic level, acts by activating or inhibiting supporting or conflicting schemas while ‘triggers’ control the initiation of activated schemas when precise timing is required (Figure 1.6). At the horizontal thread level, the first three units, perceptual system, trigger database and contention scheduling respectively account for Smith and Hancock’s perceptual cycle model.

Though proposed years after the SAS model, Smith and Hancock’s perceptual cycle model of SA is really a step back, not forward. Importantly, the SAS model accounts for willed and involuntary behaviours, a distinction which is assumed but rarely mentioned in the Smith and Hancock and Endsley’s models. It explains the mechanism by which the operators with more experience generally do better. It can be argued that their experience is encoded in a wider and more developed set of schema that frees their attentional resources to monitor the evolving aspects of situations. For example, Tenney, Adams, Pew, Huggins, & Rogers (1992, pg. 3) state that SA may vary according to pilot experience and the ability to automate: *“For each [] alerting signal or event, the crew must determine its relevance, its procedural and goal-related implications, and its urgency. Especially for the experienced crew, such events may often call forth highly practised patterns and result in ‘automatic’ responses that do not add to the workload”*.

However, and typically, when automatic processes take over an individual might display behaviour consistent with attentional wandering or task disengagement where the allocation of attention to task-relevant stimuli is reduced. Cheyne, Solman, Carriere & Smilek (2009) lists the following number of reasons that contribute to this

phenomenon: protracted, unvarying, familiar, repetitive and undemanding tasks and environments. From the SAS model, we can describe this as a mode of operation relying mostly on automatic schemas. It is not clear how the perceptual cycle model can account for this.

Furthermore, the perceptual cycle model does not offer an explanation for novel situations about which we do not have available schemas, at which point, willed action, or conscious control is required. Norman and Shallice (1986) propose that willed action is necessary to account for non-routine, novel situations. Moreover, novel or cognitively demanding tasks may require the concatenation of several schemas. Schema are considered as automatic but organising them in a specific way to meet novel or cognitively complex problems is not; some involvement of conscious and willed cognitive control is therefore necessary to account for this too. Again, it is not clear how this can fit in with the perceptual cycle model of SA.

Smith & Hancock's, as well as Endsley's, models are presently lacking in detail of how exactly the schema influence perception and perception schemas. The importance of schema for both models cannot be understated. Endsley goes as far as to state that her definition of SA is equivalent to another, previously suggested definition for the term Situation Model, which in turn was defined as "*a schema depicting the current state of the system model*" (Endsley, 1995a). Despite the critical role that both, Endsley and Smith & Hancock and others too (Sarter & Woods, 1991; Mogford, 1997) place on schema or mental models with regard to them having a fundamental function in the operation of SA, neither model offers a clear explanation of the exact processes involved and as previously noted, both models fail to venture beyond the general and rather vague indications of the central role that is assigned to

them. A detailed and verifiable description as to how precisely schemas are involved in the formation and maintenance of SA is simply missing.

### 1.6 QUANTITATIVE ANALYSIS OF SITUATION AWARENESS

First presented by Edgar, Smith, Stone, Beetham & Pritchard (2000) and later published by Edgar, Edgar & Curry (2003), the Quantitative Analysis of Situation Awareness method (QASA) is a new and promising direction of research in SA, which addresses many of the concerns raised above on other models. The QASA method assumes that processes and tendencies that happen relatively early during the situation assessment can result in different kinds of SA. In contrast to other models, which see SA as varying between good and bad, QASA suggests that many kinds of SA exist along a spectrum. At one extreme SA is based on a relatively small subset of available information (more focused) whereas at the other, SA incorporates a wider range of available information (more distributed). These can be roughly grouped into two broad categories of SA which for convenience will be abbreviated here as Focused SA (FSA) and Distributed SA (DSA). Each category is characterized by different properties (Figure 1.7), which are advantageous in some situations while being disadvantageous in others. When immediate action is required, a focused SA, FSA, which ignores a large part of available information in favour of only the most immediately relevant may be more advantageous than a distributed type SA even though the latter may be more accurate; a time/accuracy trade-off may often favour FSA to DSA in emergency situations. For example, if you wake up one morning and you find that your paint is peeling, wooden furniture gone and there is smoke coming in through the bedroom door, which problem do you deal with first? None of them of course, the house is on fire! On the other hand, situations that allow for some luxury

of time and require strategic thinking may benefit from a more careful and comprehensive assessment of all available information and therefore may benefit from a more distributed type of SA, DSA. Depending on the situation, sometimes FSA other times DSA may be more effective in reducing error and optimizing performance. It should be noted that this model is in its infancy and as such it has not been extensively tested. For example the sensitivity of this method to detect differences between different personality types or even genders or age has not been tested.

The theory behind the QASA model of SA is based on the idea that an individual uses a portion of the available information at any one time and an inherent, unconscious cognitive information bias (IB) determines the characteristics of that. IB reflects expectations about how a situation might develop and biases the attentional resources to address its expectations in such a way that the rest of the available information is gated out (Edgar & Edgar, 2007). What is filtered out may be in some ways more important than what is filtered in.

#### Characteristics associated with FSA and DSA

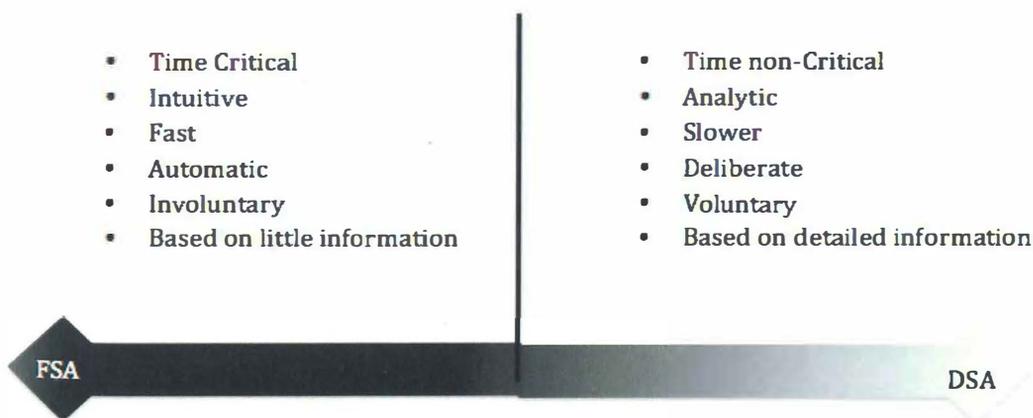


Figure 1.7: Focused and Distributed SA. FSA on the left to DSA on the right represent the opposite ends of the spectrum, which describes different types of SA with different properties.

The IB is defined as an information processing tendency that at one end denotes a relaxed information processing style whereas the other end denotes a stringent information processing style; termed as negative and positive bias respectively. How the filtering of information by a variable information bias is described in more detail below, but is assumed to rely on a criterion ‘representation strength’. Information that has a representation strength above criterion is ‘passed’, that which has a representation strength below criterion is ‘rejected’. IB as defined and measured by QASA has a particularly interesting implication; it suggests that the SA may be based only on items of a particular representation strength, which might include not only true information but also false information (Edgar & Edgar, 2007). False information, just like the true information, is based on a range of representational strengths, which can affect the confidence in the information. Confidence is not always connected to the accuracy of the representations but often to the degree with which the representation confirms prior and existing expectations. (Hertwig & Ortmann, 2004; Kahneman & Tversky, 1972).

### *1.6.1 Signal Detection Theory*

Since QASA is based on Signal Detection Theory (SDT), some basic explanation of the method is necessary (a comprehensive description of signal detection theory can be found in the work of Green & Swets (1966)). SDT is a theoretical and practical method, which can be used to model the separation of signal from noise in situations when a set of data contains both a known signal and random noise. A common example is that of detecting a target in the midst of noise on a radar screen. SDT posits two internal factors, the observer’s sensitivity (ability to distinguish between signal and noise) often measured by  $d'$  – or d-prime, and their response criterion

(specific criteria or a threshold which is used to distinguish signal from noise), measured by  $\beta$  (beta).

In a typical signal detection task, stimulus data can be plotted as two distributions (Figure 1.8 - below). The distribution on the left represents performance probability if the stimulus data only contained signal, that on the right if the data contained only noise. If the distributions are fully overlapped it represents a situation where the data contains both, signal and noise in equal measure. As can be seen from the graph, the distributions can partly overlap in which case, as is common in real life, sometime noise can be internally represented as signal and vice versa. This would be more common with ambiguous stimuli for example (McGuinness, 2007).

Depending on the response criterion, a participant or an observer may set the bar of proof (or the threshold or the bias) high before accepting a stimulus as signal, in which case s/he is being cautious, or otherwise, may decide to lower the threshold and accept most information as true. In both these cases, the first approach of caution we can term as a stringent IB whereas the latter as a lax IB.

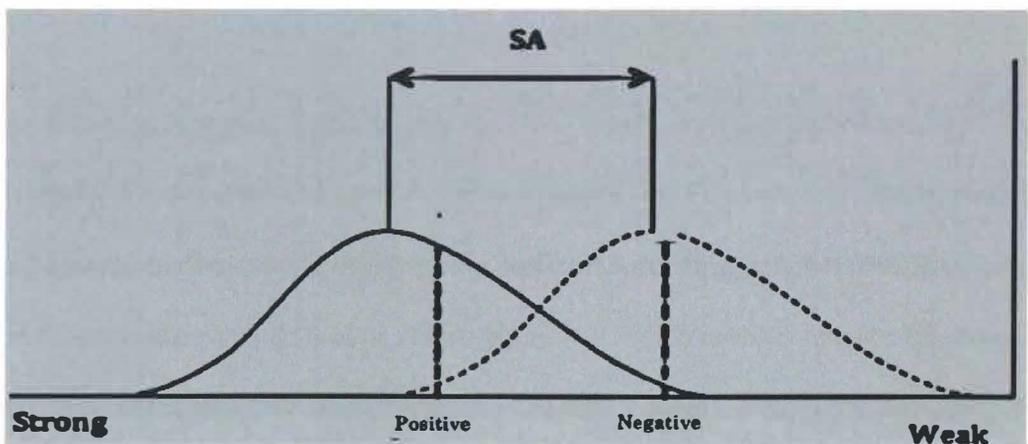
### *1.6.2 Application Signal Detection Theory in Quantitative Analysis of Situation Awareness*

In the QASA method, a series of statements are presented to an individual about a situation, for example, "Enemy unit is at position X"; half of the statements are true, half are false. Participants respond with either true or false. The responses then are used to determine the performance of the participant in terms of their ability to tell signal (true information) from noise (false information).

To avoid some limitations on the most common measure associated with the standard parametric SDT measures  $d'$  and  $\beta$ , ( $d'$ -prime assumes, for example, that the

representation strengths of signal and noise are normally distributed), the QASA method uses the non-parametric equivalents,  $A'$  and  $B''$  (that do not make any assumptions with regard to the distributions of noise and signal (Edgar & Edgar 2007)).  $A'$  is calculated and used to give an estimation of the sensitivity and  $B''$  gives a measure of the IB. Confidence ratings on each statement are also collected. That is, participants are asked to indicate on a Likert 1 to 4 scale how confident they are that the answer they have given is correct.

The quality of SA is in part reflected by the true ratio of false and true information that has gone into building the SA of an individual. Both, the capability of an individual and the degree of task difficulty are contributing factors on the ratio of false and true information that has gone into an SA (Edgar & Edgar 2007, pg. 375). Since usually there is a degree of overlap between the true and false information (Figure 1.8), IB functions as a threshold of representation strength for all available information. Below that threshold, information is considered as false and above that it is considered to be true.



*Figure 1.8: Distributions of False and True information in QASA Theory.* False and True information are represented by the distributions, right and left respectively. A strong negative IB incorporates most of true information but also more false information. The situation is reversed for strong positive IB.

Highlighting the differences between ‘knowing’ and ‘remembering’, Edgar & Edgar (2007) have argued that the distinction is reflected in different levels of confidence about the recalled information which has predictable effects on IB. Low confidence may push the IB more positive as the individual seeks to increase certainty on the information accepted as true, high confidence on the other hand may have the opposite effect. If the threshold is set high, in which case the IB moves to the left (Figure 1.8), then the criterion against which information is accepted as true becomes more stringent resulting in the SA being based in less information – in other words only information which has higher internal representational strength is accepted as true. Figure 1.8 shows how a strongly positive IB may include little false information at the cost of excluding a lot of true information. In other words, an SA that is characterized by a highly positive IB is based on potentially less information which is filtered through more stringent criteria in which case, the information on which SA is built upon is likely to be less false and more true with the trade-off that more of the true information may be rejected as false. Conversely if we have a negative bias, the information on which SA is based is most likely to include most of the true information, the trade-off being that a larger proportion of false information may also go into building the SA.

In addition to bias, the FSA and DSA types of SA are also influenced by the conditions of a situation in which the true and false distributions may be more or less discrete. If there is no time pressure there is the possibility that the individual may be able to increase the representation strength of certain items of information by gathering extra information from the environment or by corroborating the information with other sources or previous knowledge. Individual differences, such as greater expertise or experience in a situation may also change representation strengths,

although this may, as can be predicted from the discussion of schema above, also apply to false information. It can be argued that, often, perceived timing could be absolutely crucial. True and false information may become easier to separate if we think we have time to look at a situation carefully, conversely, harder if we think we are under time pressure.

### *1.6.3 Applications of QASA Tool*

The QASA method of measuring SA is still under investigation but there are some clear advantages over the other methods, if a clear link between SA and Bias is established. While we cannot infer the quality of SA from IB, knowledge of the fluctuations of IB over time may enable us to infer what kind of SA an individual is likely to have, FSA or DSA. For example, if we can infer that an individual has a highly positive IB, we may also be able to infer that that person will have an SA that is based in a restricted range of information from the totality of potentially available information and vice versa.

Note that we cannot infer directly whether a positive or negative IB indicates an advantageous or disadvantageous SA that depends on the situation. If a situation involves a large number of irrelevant distractions (more noise) for example, the filtering out of all information except what is strictly needed may help focus the cognitive and physical energies more efficiently to the task at hand. Conversely, highly positive IB may be disadvantageous when a careful assessment of all the information is needed.

A positive IB would be definitely advantageous if a soldier is performing a rescue operation under enemy fire but shortsighted if military strategists are planning a campaign within an army command centre environment. A situation, which involves

no or little ambiguity, would be represented by a clear separation of curves representing true and false information (see Figure 1.9). Conversely, a greater degree of ambiguity in a situation would be represented by a greater degree of overlap; degrees of uncertainty inherent in a situation determine the extent of overlap/separation. If IB is more negative, more of the true information will filter through but more false information will filter through also. If IB is positive, less false information is allowed through, but more true information is also filtered out. A strong positive IB, therefore, represents a narrowing down of the attention and a stringent criterion to accept information as true. The opposite, a strong negative IB represents a widening of attention to include more information and a relatively lax information mode. FSA and DSA are represented in this scheme mainly within the framework of time. For a given situation, if time is abundant, then the better separation between the false and true information may be possible which will favour a negative IB more and represent a DSA type of SA. Whereas if the opposite was true as in an emergency then the separation between true and false information is harder favouring a stronger positive IB representing an FSA type of SA.

Initial studies have shown a strong negative correlation between IB and SA (Edgar & Edgar, 2007). In a landmark QASA study reported by Edgar, Edgar, & Curry (2003), the QASA method was tested in a command and control, war game scenario simulation which was enacted in a terrain model facility (Figure 1.10); the blue forces were fighting against the red forces. Four commanders controlled four commands in the blue forces, A, B, C and D. Communications between commanders were carried out only via written messages, which meant all communications could be monitored. All red units were 'hidden' unless it was judged that blue units on the ground could 'see' red units.





Figure 1.10: Photograph of the Terrain Model used in the *QASA* Study. The terrain was a real model of an area in Germany.

Commanders, A, B, C and D controlled the blue forces in the war game scenario. The probe statements were designed to address the three levels of SA in accordance with the SAGAT model, for example:

- *Perception: A has crossed the river at point x.*
- *Integration (as opposed to Endsley's comprehension): The strongest enemy force is present in area A.*
- *Projection: At time x you will reach point y (scored post-hoc)*

Other classifications were also used, such as use of relevant versus non-relevant information. Generating the measures of SA and IB based on Signal Detection Theory, Edgar et al., (2003) found that IB was indeed negatively correlated with SA. They also observed a particularly interesting behaviour of commander D, he appeared to have no perceptual level SA at all whereas at the same time showing a comparatively normal integration and projection levels. It suggested that SA was not only achieved in a hierarchical manner whereby information is linearly integrated from perception up to projection, but instead, SA may be built from a top-down

direction too; in other words, prior knowledge, expectations and other unconscious processes may all contribute to the final Situation Awareness.

A follow up study (Edgar et al., in press) tested the influence of IB in information processing in conditions where participants previous knowledge and expectations were tightly controlled. Participants were required to detect a pattern or category based on the feedback they received from their choices. Halfway through 104 trials, unbeknown to the participants, the category was changed and the effect of that could be traced on the second half of the test. Based on the Wisconsin card sorting task (WCST) (Berg, 1948; Grant & Berg, 1948), the task involved two crucial features; 1) it was possible to track participants SA and IB as progressing completely independent from prior knowledge and experience (the task was deliberately bare), 2) the forced loss of SA halfway through could mimic situations when the SA of a participant is misleading due to an undetected change in the situation. Again, a clear negative correlation was found between SA and IB. However, for participants who showed an IB tendency towards the positive, cautious end, the correlation was somewhat modulated by the forced loss of SA; a move towards positive correlation between IB and SA was found after the category change for this group. A tentative explanation about this is that the forced loss of SA may have produced a negative emotional arousal, which has made participants more careful about accepting information as true (Derryberry & Tucker, 1994).

A further study using the same paradigm but in a more realistic settings was conducted including a crucial additional feature, an affective element in the form of feedback on the body count of lives lost/saved linking incorrect and correct decisions to lost or saved lives. SA and the subsequent decisions in this scenario had consequences. Edgar et al., (in press) found that the negative affective component

may have had an influence on the direction of the IB towards the positive end of the scale suggesting a more cautious approach to accepting information as true.

The SA literature and research has so far not investigated how brain activity may be related to the different aspects of SA, nor is it clear how SA, as is presently conceived, may reflect the way that the brain functions. Endsley (1995) took the explicit position that the concept of SA, as she defined it, was beyond the reach of psychophysiological measures arguing that it is not possible to infer from such measures the sort of memories and awareness of a participant. While this is of course self evident, the content of the thoughts cannot be inferred by EEG or fMRI readings, nonetheless, knowledge about the brain activity, especially EEG recording which can be carried out in real-time and millisecond precision, may enable us to infer what sort of SA a person is likely to have. In particular, SA itself involves a comparison with the external situation, which is therefore intractable to measures of brain activity. Bias, on the other hand, is proposed to be a criterion that is set internally by the individual and so the brain activity underpinning this criterion-setting (bias) process may be amenable to study using EEG. Neuroscience can inform us about which brain systems are active at key intervals in a situation and we may be able to infer from that which processes may be operational at which junctures.

It is also worth to keep in mind that *'the perils of inferring the mind from measuring the brain are not all that different from those encountered when attempting to infer the mind from measuring behaviour'* (Barrett, 2009). While Endsley's current definition of SA does not allow for contributions from brain research, the IB may provide an elegant way to take advantage of the research in brain activity and psychophysiological measures, especially with regard to EEG. The position taken here is not against developing subjective measures of SA. Many studies show them to

be useful, however, a full theoretical and detailed description of SA would greatly benefit from an account of how it is manifested in the brain.

### 1.7 SUMMARY

SA is a widely used psychological concept with the potential to increase safety, improve performance, and reduce error in a vast range of high-risk human professions. However, some of the main models of SA, such as Endsley's, have not yet fostered wide support in the psychological domain and have been the subject of, sometimes stern, criticism. Circular reasoning is often cited as a major issue with regard to the current SA theories; the conceptual separation of SA from decision making has also been highlighted as, at best, not well justified. The freeze-probe technique has also been criticised and, furthermore, caution has been urged on the grounds that interpreting interruption based measures may be dependent on the construct used to generate the queries. Also an argument is made that hindsight reasoning may affect responses and the way in which questions that are generated may lack ecological validity. A further important failing is in the lack of detail that is often characteristic of the current SA models and finally, and somewhat surprising, is the complete lack of theoretical and ground work on how the emotions and the neural systems are involved.

This thesis aims to investigate further the concept of IB and its underlying neural correlates and furthermore, to investigate how emotions may be involved in achieving, maintaining and updating SA within a dynamic environment. An attempt will be made to develop ways to circumvent the freeze-probe techniques via the use of psychophysiological tools, such as EEG.

## **Chapter 2 - Emotional Aspects of SA Functioning:**

### **Theoretical Background**

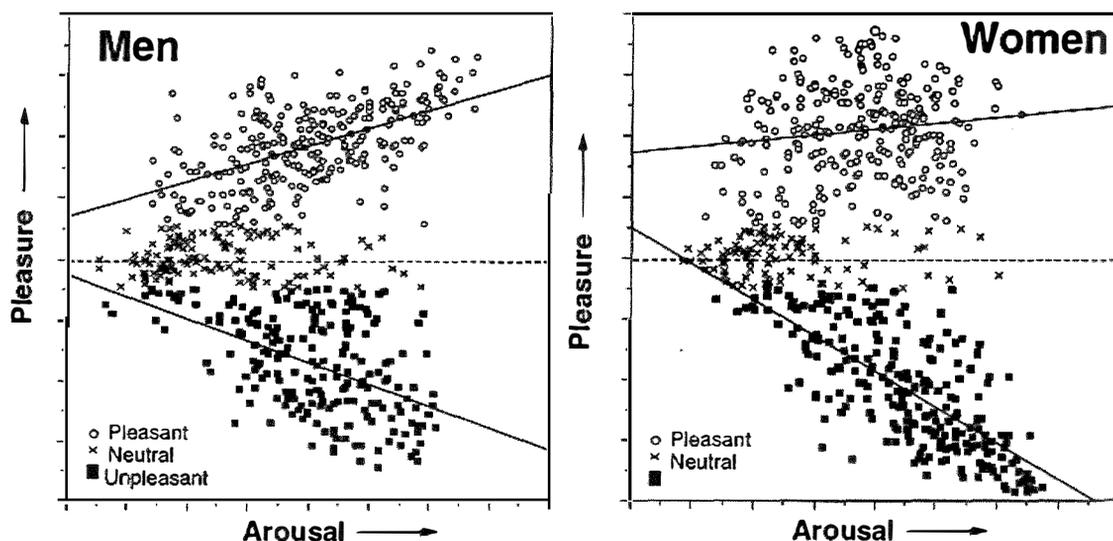
#### 2.1 INTRODUCTION

Having its main applications in areas that involve high risk, including the possibility of the loss of life, the study of SA is especially important and relevant within the context of emotive situations. Since the effects of emotion in the processes of SA are vastly understudied, the exploration of this relationship is the focus of this thesis in general, and this chapter in particular.

Emotions, that are defined here in terms of three major dimensions of valence, arousal and dominance (Lang, Bradley & Cuthbert, 1997), are related to many cognitive processes, such as attention, memory, learning and decision-making; all of which are important psychological constructs in the understanding of SA (Endsley, 1995). The first two, affective valence (ranging along the axis of pleasant to unpleasant) and arousal (ranging from calm to excited) are considered as the primary dimensions of emotions (Lang, Bradley & Cuthbert, 1998). All emotions can be represented along the varying degrees of the affective axis of valence and arousal (Figure 2.1).

The evidence for emotional involvement in cognitive processing suggests that different degrees of involvement of the affective systems are underpinned by the dominance of either approach or avoidance motivational systems (Ito, Cacioppo, & Lang, 1998; Norris, Gollan, Berntson, & Cacioppo, 2010). At a relatively low emotional involvement, when there are no present threats in the environment, there is a tendency for the approach behaviours to dominate over avoidance behaviours

(Cacioppo & Gardner, 1999). Conversely, when the situations present some degree of threat there is an increased sensitivity to potentially negative stimuli and the avoidance behaviours tend to dominate. As the attentional resources are directed to either potential-threat or potential-reward related information by the processes of attention, it can, logically, lead to radically different internal representations of situations. In this chapter and the next, the research into the effects of different emotions on attention, memory, (this chapter) and decision-making (the following chapters) will be examined and their relevance to the SA research, as a whole, will be discussed.



*Figure 2.1: Distribution of pictures from the IAPS Set. “A sample is shown of men and women, plotted in a two-dimensional affective space, defined by the mean ratings of pleasure (y-axis) and arousal (x-axis) for each stimulus. The separate limbs of the overall boomerang-shaped distributions are consistent with the hypothesis that emotional reactivity is organized by two underlying neural systems—appetitive and defensive—that each vary in arousal.” (Taken from Lang, Bradley & Cuthbert 1998).*

The first section of this chapter is concerned with emotional involvement in the cognitive processes of attention and memory. There is accumulating evidence which suggests that different degrees and types of emotional involvement affect the

processes of memory (e.g. Cahill, Prins, Weber, & McGaugh, 1994; Guy & Cahill, 1999) and attention (e.g. Friedman & Forster 2010; Fredrickson & Branigan 2005) differently and that their effect on these processes, arguably, bears direct relevance to the current measures of SA. Following the literature review on these topics, the second section of this chapter will examine how different emotional states are reflected in the QASA measure of SA. It will be argued that the assumptions underlining the QASA model are particularly well suited to evaluate the workings and effects of emotions on SA.

### *2.1.1 General Mechanisms of Attention*

It has been known for a long time that attention selection mechanisms are modulated by the limited processing capacity of the sensory systems; therefore some stimuli are preferentially processed over other stimuli (Broadbent 1957; Neisser, 1967). Which stimuli are selected for further processing is determined by the operations of, what have been called, attentional filters (Driver 2001) which are driven both by “*bottom-up*” and “*top-down*” cognitive processes (Corbetta & Shulman, 2002). In a review of the neural circuits underlying attentional function, Corbetta and Shulman distinguish different but partly overlapping neural circuits underlying these two systems. According to Corbetta and Shulman, the top-down, goal-directed processes of attention are underpinned by activity in the intraparietal cortex and superior frontal cortex. The bottom-up attentional processes, which are primarily underlined by the activity in the right hemisphere and also involve the temporoparietal cortex and inferior frontal cortex, specialize in the detection of behaviourally relevant, salient, or unexpected stimuli that are important in the preparation of goal-directed behaviours (Corbetta & Shulman, 2002).

The operations of either system are determined by different factors. Kastner & Ungerleider (2000) cite stimulus salience (such as high contrast) as one such factor important in the bottom-up processes of selective attention. Also, top-down influences, as in goal-directed behaviour, can override the bottom-up influences and force attention to stimuli which may be less salient but more relevant to the goal at hand.

Kastner & Ungerleider (2000) suggest that the biased processing of information may be reflected in a range of neural circuit modifications such as, (a) the enhancement of neural responses to attended stimuli, (b) filtering of unwanted information by counteracting the suppression induced by nearby distracters, (c) the biasing of signals in favor of an attended location by increases of baseline activity in the absence of visual stimulation or (d) the increase of stimulus salience by enhancing the neuron's sensitivity to stimulus contrast.

In addition to bottom-up and top-down processes, there is a large body of cognitive and imaging research, which suggests that attentional filters are also influenced by emotional processes - the foundation of which is underlined by the activation of general avoidance/approach motivational systems (Bradley, 2009). Which of these two systems is dominant determines, according to Bradley (2009), a cascade of perceptual and motor processes that aim to end up with the selection of an appropriate behaviour suggesting that, therefore, the selective attention filters are also modulated by the motivational systems.

### *2.1.1.1 The Relationship Between Attention and Emotion*

How are the emotive stimuli capable of triggering avoidance or approach behaviours moderated by the processes of selective attention? Compton (2003) suggests a two-stage process. In the first stage, emotionally-potent stimuli are initially processed by

sub-cortical and limbic areas including the amygdala. In the second stage, the stimuli are filtered by the sub-cortical emotional regions, and are then prioritized for further processing via selective attention. Inputs from the amygdala and the frontal lobe regions then converge to drive the selection of appropriate behaviours, as well as maintaining representations in working memory (Compton, 2003). The idea is that attentional processes preferentially select emotionally - potent stimuli; there is evidence that supports this conclusion (see below).

For example, Öhman, Flykt & Esteves (2001) reported that participants were quicker to find fear-relevant images (snakes or spiders) as opposed to fear-irrelevant images (flowers or mushrooms). Furthermore, they reported that participants, who were specifically fearful of one of the fear-relevant stimuli but not the other, facilitated their search for their respective fear-relevant object but showed no differences in the processing of fear-irrelevant stimuli. In other words, general threatening stimuli had the effect of capturing the processes of selective attention quicker compared to non threatening stimuli and, further confirming the findings, the effect deepened if the stimuli was personally threatening to participants. Furthermore, Vuilleumier, Armony, Driver & Dolan (2001) who scanned the participant's brain in fMRI while performing a matching task for pairs of stimuli in pre-specified locations and in the presence of other irrelevant stimuli, found that when faces or houses appeared in the unspecified locations, the right fusiform gyrus, which is an essential area for processing faces (Bokde, Lopez-Bayo, et.al., 2006), was more strongly activated by the faces that had a fearful expression. The amygdala on the other hand, which is related to the processing of threat-related stimuli and acquisition of fear-conditioned responses (Vuilleumier et al., 2001), was un-differentially activated in response to the fearful faces regardless whether the fearful stimuli appeared in the

pre-specified location or not; a finding also confirmed by Phelps, Ling & Carrasco (2006). This supports the idea that the processes of selective attention preferentially process the emotional stimuli and that the amygdala plays an important role in this process.

The next section will consider how stimuli that have passed through the attentional filters are integrated with items in memory.

### 2.1.2 *General Mechanisms of Memory*

There are three core processes that describe memory; encoding, storing or consolidating and recalling information. Encoding refers to those memory processes that convert, or transduce, information from various sensory modalities into a psychological/neural construct that can be stored or recollected at a later time. According to the “*encoding specificity principle*” (Donald, & Tulving, 1973) such encoding processes - which are closely related to learning processes that include association learning as well as processes of classical and operant conditioning - leave a “*memory trace*” that includes the contextual cues within which the memory was originally formed. After a memory trace has been acquired, a consolidation process occurs. This consolidation process is further sub-divided into 1) synaptic potentiation, which takes place over minutes and hours, and 2) system consolidation, which takes place over weeks, months or years (see Dudai, 2004 for an extensive review); the former is dependent on the activation of the local nodes in the neuronal circuits that encode the experience-dependent internal representation, whereas the latter may involve large scale reorganisation of the brain circuits through which the original memory trace retains its dependence in the neural circuits involved in the acquisition but may also spread to new locations in the brain (Dudai, 2004). Memory retrieval, on

the other hand, encompasses the processes through which a stored memory is re-activated as and when required. There are three main types of memory retrieval paradigms; free recall, cued recall and serial recall all of which have been used by researchers to study the memory processes in both humans (e.g. Page & Norris 1998) and animals (e.g. Botvinick, Wang et al., 2009).

As has been discussed above (section 2.1.1.1) the processes of emotional processing and attentional processing appear highly related. Evidence also suggests that attentional processes are more important to some memory processes and less in others. For example, it has been shown that encoding processes, but not storage and recall processes of memory, are selectively disrupted by tasks that involve divided attention ( Craik, Naveh-Benjamin, Ishaik & Anderson (2000). In conditions where a parallel task (which divides attention) is performed concurrently during the encoding stage the retrieval process is impaired Craik et al., (2000). This indicates that attentional processes are particularly important during the encoding stages.

The effects of emotional processes on memory appear to be broader and, as will be argued, the effects of different emotions during the encoding and the subsequent effects observed during the recall stage are particularly important with regard to SA.

#### *2.1.2.1 Emotion, Memory and Attention*

Perhaps the most dramatic demonstration of the interrelation between an emotional event and the subsequent memory traces and their effects can be seen in the case of Post-Traumatic Stress Disorder (PTSD). A mental disorder that often has a known negative emotional trigger (major threat to self, intense fear, hopelessness or horror), PTSD has profound and persistent effects on both the processes of memory formation

and consolidation, and those of attention (Steinmetz, Scott, Smith & Kensinger, 2012). Characterised by an amygdala-based increased fear response associated with a specific traumatic event, PTSD involves re-experiencing of the symptoms, intrusive memories and nightmares, flashbacks, emotional numbing, amnesia and cognitive avoidance (Diagnostic and Statistical Manual of Mental Disorders – DSM IV). It is suggested that two important brain circuits, the amygdala and the hippocampus; the first associated with emotions (Amunts, Kedo, Kindler, Pieperhoff, Mohlberg, Shah, Habel, Schneider & Zilles, 2005), the other with memory formation (Eichenbaum, Otto, Wible & Piper, 1991; Squire & Schacter, 2002), are involved in the generation and maintenance of the PTSD symptoms (Shin & Liberzon, 2010).

Less dramatically but yet important, varying degrees of emotional arousal are shown to have a differential effect in memory feature binding, which is the way in which we select features of perceptual objects and organize them into a comprehensive whole (Triesman, 1998). A study carried out by Mather, Gorlick & Nichole (2006) looked at the emotional arousal effects in memory feature binding. On a series of successive trials, participants were presented with four pictures of high, medium and low emotional arousal and were asked to monitor and remember the locations of the pictures on the screen. They found that memory for picture location worsened as emotional arousal increased and that, furthermore, participants with higher depression scores had the worst memory for the location of the negative pictures. This was correlated with differential activation in several brain structures. Functional magnetic resonance imaging (fMRI) showed that, relative to people with low arousal, people with high arousal showed increased activity in the fusiform gyrus, middle temporal gyrus/middle occipital gyrus, lingual gyrus) and less activity in superior precentral gyrus and the precentral superior temporal intersect. Mather et al.,

(2006) concluded that high arousal and negative valence stimuli, attract attention in such a way that the normal functioning of working memory is disrupted, leading to the impaired binding of memory elements. Likewise Cahill, Prins, Weber, & McGaugh, (1994) and Guy & Cahill (1999) have shown an enhanced memory encoding for information presented within a negative emotional context. The effect was diminished when participants were injected with an adrenergic antagonist (propranolol hydrochloride) (Cahill et al., 1994). This supports the idea that through its effects on attentional systems emotional arousal is involved in biasing the processes of memory encoding and consolidation.

Other evidence suggests that memory is also often distorted or condensed under conditions of emotional stress (Anderson, Lisa, Shimamura & Arthur, 2005). In an influential study, Christianson & Loftus (1991) presented to a large number of participants (397 in total) a series of themed slides in which only one slide of the set was presented twice with varied emotional content, from negative (women injured near a bicycle) to neutral (women riding a bicycle). Participants who watched the emotional slide (prime) were better able to recall central details about the slide, whereas the recall of peripheral information was impaired in comparison to participants that watched the neutral slide. When they exchanged the emotional slide for one containing novel stimuli - a women carrying the bicycle in her shoulder - they found that the recall for that particular slide was worse equally for peripheral and central information. This study suggests that emotionality (but not novelty) is responsible for a mode of attentional processing that has increased central and decreased peripheral acuity. Christianson & Loftus also reported from participants' reflection on the experiment that they elaborated differently the elements of a situation if the slide contained emotional, neutral or novel stimuli. Similarly, Hulse &

Memon (2006, 2007) found that in emotional situations people form enriched memories but these memories, however, are usually centered around the location of the emotional stimuli, a behaviour which could be explained by involvement of the amygdala (Phelps & LeDoux, 2005; Compton, 2003) leading to the attentional tunneling effect (attention narrows down to the elements that are perceived as most threatening). While the function of the increased capability to filter out superfluous information in threatening situations may be evolutionary adaptive, in situations where a careful assessment of information is needed, the attentional tunneling effect may hinder rather than help. This precise conclusion was reached many years earlier by Kohn (1954) who wrote: "*Under conditions of stress...the perceptual field is constricted or narrowed, and the scope or span of behaviour tends to be restricted to those elements which contribute most to the direction of behaviour, or to those elements which appear to be the most threatening.*" (p. 290).

Contrary to the effects of negative emotional arousal on the processes of attention and memory, positive emotional arousal may contribute to a broadening of attentional scope. Fredrickson & Branigan (2005) tested 104 participants on emotions such as amusement, contentment, neutrality, anger and anxiety; participants watched a movie appropriate to each emotion. They found that, in comparison to the neutral state, the positive emotional states were associated with a broader attention span as opposed to negative emotions, which were associated with a narrowed attention span. This effect extends to both explicit and implicit emotional states. Furthermore, Friedman and Forster (2010) reported that an extensive body of the research literature on this topic supported the proposition that the scope of attention widens or narrows with positive or negative implicit emotional states respectively. They suggested that this was an indication that emotional involvement changes the shape of cognitive

processing as well as the content. In other words, it changes not only what information is processed but also how it is processed.

The cost of the attentional tunneling is poor overall memory formation for some possibly relevant situational elements (Wessel & Merckelbach, 1998) whereas the benefit is that if peripheral information is not needed, than filtering it out may help to improve performance. Such tunneling of information, however, may impact on the underlying mental model of a situation and thus may also impact SA (Endsley, 1995). Given that QASA already assumes that sometimes SA is based on a restricted scope of information (focused situation awareness - FSA) and sometimes in a wide scope (distributed situation awareness - DSA), there is some credibility to the hypothesis that the effects of emotion on the processes of attention, at least in part, determine the scope of SA and that QASA should be sensitive to those changes. An important practical question, therefore, is whether the QASA measure can be used to detect the effects that different levels of emotional arousal have on SA.

In the following experiment the focus is on exploring the relationship between different emotional states and SA. According to the evidence discussed so far, negative emotional arousal should have an effect on IB such that the IB becomes more positive under negative emotional arousal and more negative under positive emotional arousal underlying the FSA and DSA types of SA respectively. In other words, with negative arousal, there may be a more conservative filtering of information, while with positive arousal there may be a more liberal approach. To test this in the following experiment, participants' emotional states were manipulated using three sets of standardised emotional pictures, negative, positive and neutral, selected from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2005) and their SA and bias were measured using QASA technique.

## 2.2 EXPERIMENT 1: EMOTIONAL INFLUENCES ON SA AND BIAS AS MEASURED BY QASA

The following experiment consisted of a scripted war-fighting scenario with the participant viewing the scene from the vantage point of one of the combatants. The task was inherently changeable and dynamic and the participants were asked at different points to answer a series of questions that were presented as coming from the 'headquarters'. The participants' anxiety levels pre and post experiment were measured using the State Anxiety Inventory (SAI).

Three main hypotheses were tested:

- 1) *Negative and Positive emotional arousals will have a different effect on IB with the Positive emotional arousal causing IB to become more negative (on the QASA scale) and Negative emotional arousal causing IB to become more positive (on the QASA scale).*
- 2) *Different types of emotional arousal will have a different effect on SA in the situation assessed, with Positive emotional arousal improving SA as measured by QASA, and the Negative emotional arousal impairing SA.*
- 3) *Negative and Positive emotional arousals will have a different and opposing effect on the correlation between IB and SA. That is, negative emotional arousal will reverse the negative correlation between SA and IB. In other words, in the negative arousal affective condition the relationship between the IB and SA will be such that when the IB decreases, the SA also decreases whereas for the positive emotional*

*arousal affective condition the relationship is such that when IB decreases the SA increases.*

### 2.2.1 Method

#### 2.2.1.1 Participants

Forty-five participants were randomly selected (opportunity sampling) mainly from students of the first year of the Psychology degree at the University of Gloucestershire. Participants were equally divided into three groups of 15 participants, each group to one emotional condition: positive (mean age = 24.60 SD = 3.48, 4 female), negative (mean age = 23.33, SD = 3.62, 3 female) and neutral (mean age = 23.13, SD = 2.95, 2 female).

All participants had self-reported normal or corrected-to-normal vision. All participants signed a consent form accepted by the Ministry of Defence Research Ethics Committee (see Appendix B) prior to taking part in the study. Participants were not offered any monetary reward for taking part in the study and had the right to withdraw at any time without giving an explanation.

#### 2.2.1.2 Materials

##### Spielberg State Anxiety Inventory

The Spielberg State Anxiety Inventory subset from Trait/State Anxiety Inventory (STAI) is a validated emotional anxiety assessment questionnaire used to generate separate measures of State and Trait Anxiety. The subset of STAI, State Anxiety Inventory (SAI) was used to confirm that the negative IAPS images induce negative affect and positive IAPS images induced positive affect relative to the neutral IAPS

images. SAI is comprised of 20 self-report type questions. Initially proposed and developed by Spielberg (1989) SAI is widely used in psychological experiments and has been adapted for cross-cultural research in more than 30 languages.

STAI has gone through extensive reliability and validity testing that make it a valid instrument for use in both research and clinical settings (Sesti, 2000). Several items on the STAI are reverse coded (items 1, 2, 5, 8, 10, 11, 15, 16, 19, 20). Internal consistency coefficients for the scale have ranged from .86 to .95; test-retest reliability coefficients have ranged from .65 to .75 over a 2-month interval (Spielberger et al., 1983). Considerable evidence attests to the construct and concurrent validity of the scale (Spielberger, 1989).

#### International Affective Picture System (IAPS)

Sixty colored pictures were selected from the IAPS (Center for the Study of Emotion and Attention, 1999) consisting of 20 positive, 20 neutral, and 20 negative pictures, based on valence (a bipolar continuum with negative and positive poles measured as hedonic distance from neutral) and arousal (a continuous axis of intensity increasing from low to highly arousing.) ratings. Positive pictures included erotic couples and happy families; neutral pictures included neutral faces and household objects; negative pictures included mutilated bodies and scenes of attack and threat. Positive and negative pictures were selected to be the most arousing exemplars in the respective subcategory. Normative ratings of valence and arousal for pictures in these categories differed (Table 2.1 below):

1. *Emotional calibration set (n = 6):* 5760, 5780, 5750, 7492, 5825, 5725.
2. *Positive Set (n = 20):* 2050, 2070, 2080, 2160, 2165, 2170, 2311, 2340, 2341, 2360, 4650, 4651, 4652, 4658, 4659, 4660, 4664, 4670, 4680, 4690.

3. *Neutral Set (n = 20)*: 2190, 2200, 2210, 2230, 2381, 2440, 2480, 2570, 2850, 7002, 7009, 7010, 7020, 7030, 7040, 7080, 7175, 7233, 7235, 9070.
4. *Negative Set (n = 20)*: 1050, 1120, 1201, 1300, 1930, 3000, 3010, 3051, 3060, 3071, 3080, 3102, 3110, 3130, 3530, 6260, 6350, 6510, 6540, 9405.

Normative rating of Arousal and valence for the four sets of chosen photos				
	Calibration (n = 6)	Positive (n = 20)	Neutral (n = 20)	Negative (n = 20)
Arousal (mean)	4.01	5.7	2.6	6.4
Valence (mean)	7.45	7.4	4.9	2.6

Table 2.1: Normative Ratings for Valence and Arousal. Normative ratings are given for all the IAPS photo sets selected, Calibration set plus Positive, Neutral and Negative sets.

### Quantifying and Analysing Situation Awareness (QASA) tool

QASA is an SA measurement tool/technique based on signal detection theory and developed by Edgar & Edgar (2007) which measures an individual's ability to tell false from true information (A') and detects and measures the inherent information bias (B'') in the answers (see Chapter 1, section 1.6 to 1.6.2 and Appendix A "QASA tool"). Below are the actual algorithms (Equation 2.1) used to calculate the Information Bias (B'') and the Situation Awareness (A') score (Equation, 1).

### QASA ALGORITHMS

$$A' = 0.5 + \left( \text{sign}(H-F) \frac{(H-F)^2 + |H-F|}{4\max(H,F) - 4HF} \right)$$

H = 'Hit' rate

F = 'False alarm' rate

max (H,F) = either H or F, whichever is greater.

$$B'' = \text{sign}(H-F) \frac{H(1-H) - F(1-F)}{H(1-H) + F(1-F)}$$

Equation 2.1: QASA Equations. Here are the actual algorithms used to calculate the A' (which is the SA score) and the B'' (which is the Information Bias score).

The algorithms were implemented in an excel spreadsheet by Dr. Graham Edgar, (please see Appendix for a copy of the calculating sheet) which was used to calculate the SA and IB scores for each participant. Included in the Appendix is also a 'QASA tool - instructions' (Edgar, personal communication) which outlines step-by-step instructions on how to use the Excel sheet to calculate the IB and SA scores. The IB and SA scores were calculated for each participant separately. As well as the measures of SA provided by the analysis as described above, participants were also asked to rate, on a four-point scale (guess, fairly uncertain, fairly certain, certain) how confident they were that each answer they to the T/F probes was correct. All scores (A', B'' and confidence) were then rescaled to give a score in the range -100 to +100.

Score	A' - Situation Awareness (SA)	B'' - Bias	Confidence
<b>Positive (max +100)</b>	Good SA. Can tell true information from false: higher score is better.	'Strict' bias. Tendency to reject information as false even if true. The higher the score the greater the tendency to reject information as false.	Indicates a <i>belief</i> that the responses given are correct, suggesting a belief that SA is good. A higher score represents greater confidence.
<b>Zero</b>	No SA – guessing?	No bias towards accepting or rejecting information. A 'neutral' attitude.	Does not believe answers are predominantly either correct or incorrect.
<b>Negative (max -100)</b>	Misguided. Believes false information is true and <i>vice versa</i> . More negative is worse.	'Lax' bias. Tendency to accept information as true even if false. The more negative the score the greater the tendency to accept information.	Indicates a belief that the responses given are wrong, suggesting a belief that SA is poor.

Table 2.2: *Interpretations of the SA, Bias, and Confidence Scores*: Interpretations of the SA, bias, and confidence scores provided by the QASA tool.

### Stimulus Presentation Computer

Stimulus presentation was controlled by e-prime version 2.0 (PST, Inc.), running on a Dell PC, using Microsoft Windows XP with Service Pack 2.

Each image was presented on a 0.48m diagonal, 4:3 aspect ratios computer screen with a frame refresh rate of 60 Hz. The screen was placed 1.5 m in front of the viewer, resulting in a picture presentation with a visual angle of 14.7 degrees of visual angle horizontally and 11 degrees vertically.

#### *2.2.1.3 Design*

This was a between-participants design with type of emotional arousal induced as the between-participants independent variable with three levels (positive, negative or neutral emotional arousal). The experiment simulated a war-fighting scenario, which was operationalized as a rapid series of individual slides (408 in all) presenting a military mission. At six semi-random intervals within the presentation participants were presented with blocks of eight QASA probes concerning the situation presented on the previous slides. Confidence measures on four-point Likert scale were also collected.

Participants first completed the SAI inventory and then affect was manipulated using the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 1997, 2008); a series of pictures validated and rated as generating different affects (emotions). Pictures were chosen to generate positive, neutral or negative affect. A series of twenty IAPS pictures of the appropriate affect category were shown to the participant prior to the scenario. IAPS slides were then interleaved

with the scenario slides at pseudo-random intervals of 8-13 slides. On completion of the task, participants again completed the SAI inventory.

#### *2.2.1.4 The Main Experimental Hypotheses*

1) *Experimental Hypothesis 1*: Negative and Positive emotional arousals will have a different effect on IB with the Positive emotional arousal causing IB to become more negative (on the QASA scale) and Negative emotional arousal causing IB to become more positive (on the QASA scale).

*Null hypothesis*: There is no effect of emotional arousal on IB.

2) *Experimental Hypothesis 2*: Different types of emotional arousal will have a different effect on SA in the situation assessed, with Positive emotional arousal improving SA as measured by QASA, and the Negative emotional arousal impairing SA.

*Null hypothesis*: There is no effect of emotional arousal on SA.

3) *Experimental Hypothesis 3*: Negative and Positive emotional arousals will have a different and opposing effect on the correlation between IB and SA. That is, negative emotional arousal will reverse the negative correlation between SA and IB. In other words, in the negative arousal affective condition the relationship between the IB and SA will be such that when the IB decreases, the SA also decreases whereas for the positive emotional arousal affective condition the relationship is such that when IB decreases the SA increases.

*Null hypothesis*: There is no effect of emotional arousal on the correlation between IB and SA.

### 2.2.1.5 Procedure

Participants were given full written descriptions of the task (see Appendix B). Participants were then asked whether they had any questions and required to sign a consent form before proceeding any further (See Appendix B). All but one volunteer elected to participate in the experiment.

Participants were then seated in front of the computer and were instructed to start the task. After starting the e-prime experiment, the experimenter left the testing room but remained within earshot of the participant.

The experiment is outlined below in a step-by-step fashion; the procedure was identical for all participants:

1. The e-prime experiment started, participant asked to provide the following details in the given order
2. Subject Number
3. Session Number
4. Subject Identifier (participants were encouraged not to use the real name)
5. Subject Age
6. Subject Sex
7. Subject Handedness
8. Researcher ID
9. Summary of Start up Information
10. **Welcome Message presented on screen:** Welcome to the experiment. Please read the instructions before each of the following tasks carefully. Please ask any questions you might have before proceeding with the tasks. We hope you will enjoy it. Press Spacebar when you are ready to continue.)

11. **Instructions presented on screen:** *“Next, you are required to complete a (SAI) questionnaire. Please be aware of the following: 1) Once a question has been answered, you CANNOT go back to change your answer. 2) Please do not click outside of the Big Green boxes because that will terminate the programme. [Participants were verbally informed to notify the experimenter if that happened – there were no such cases.] Press spacebar to continue...”*
12. **Questionnaire instructions presented on screen:** *A number of statements which people have used to describe themselves are given. Read each statement and then click on the answer, which corresponds most closely to how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your feelings best. Please press spacebar when you are ready.*
13. Participants were presented with the question at the top left of the screen.  
Response options were:
  1. Not at all
  2. Somewhat
  3. Moderately so
  4. Very much soand were presented on screen beneath the question (Figure 6).  
Four 4X5 cm green coloured boxes were arranged horizontally on the bottom of the screen each box labelled by numbers from 1 to 4, from left to right.
14. After each selection, participants were presented with the question and their selected response (Figure 2.2).

15. The experiment was programmed to add the scores automatically after each response in accordance with the instructions in the STAI manual.

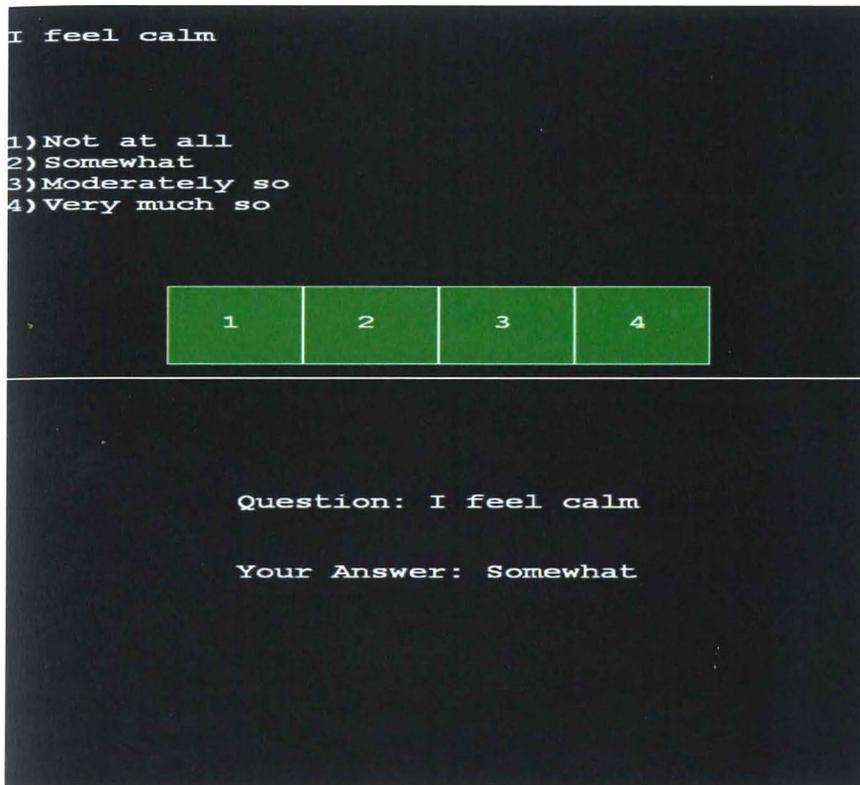
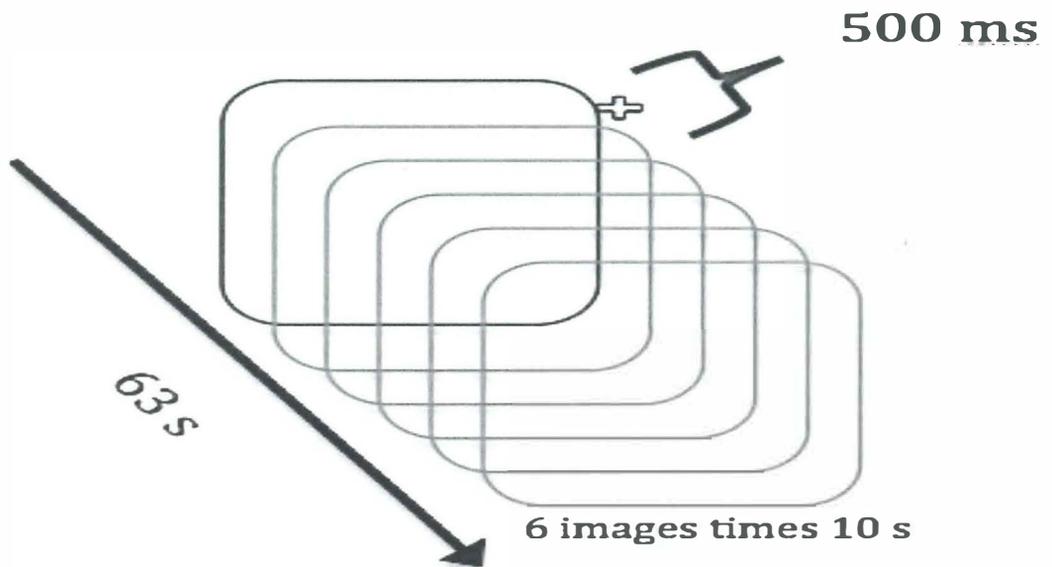


Figure 2.2: SAI Questionnaire. Figures above show how the SAI questionnaire was presented to participants on the computer screen. The top picture shows the presentation of questions along with the answering options, the lower one shows the feedback after participants' answer each question.

16. After the questionnaire, a message appeared on the screen alerting the participant to the start of the next step. The message read as follows: *"Please just sit still and keep your eyes on the images for the duration of the next slides. Press spacebar when you are ready..."*
17. Six images selected from Emotional calibration set (see materials section) were presented for 10 seconds each in the same order as given in the set. A fixation cross in the middle of the screen was presented for 500 ms between each image (see Figure 2.3).



*Figure 2.3: Calibrating Emotions.* Participants are presented with 6 images, which stay on screen for 10s each, presented at 500ms intervals. This presentation was the same across all groups and it was used as way of calibrating the participant's emotional arousal to the same level across all groups.

18. E-Prime was programmed to randomly assign the participant to one of the conditions, Neutral, Positive or Negative. If one category reached the target number of participants (15) then the experiment was programmed to assign participants into one of the two remaining categories.
19. Instructions for the next step appear on screen reading: *"Please look attentively at the following series of photos. You might be asked questions about them later."*
20. Participants saw either the Neutral, Negative or Positive set of IAPS photos appropriate to the randomly assigned emotional condition in the same order given in the set (see Materials section for information on photo sets; see Figure 2.4 for duration information).

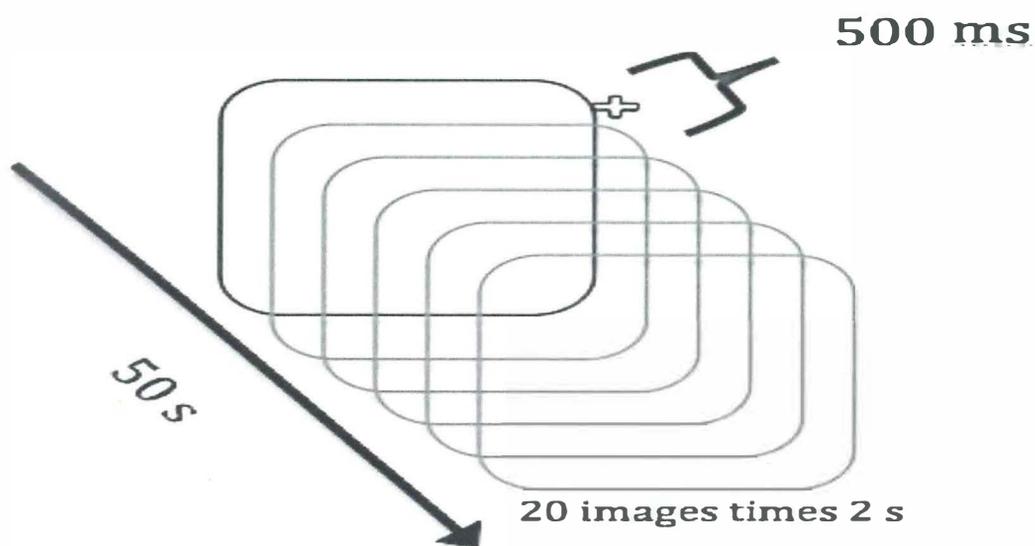
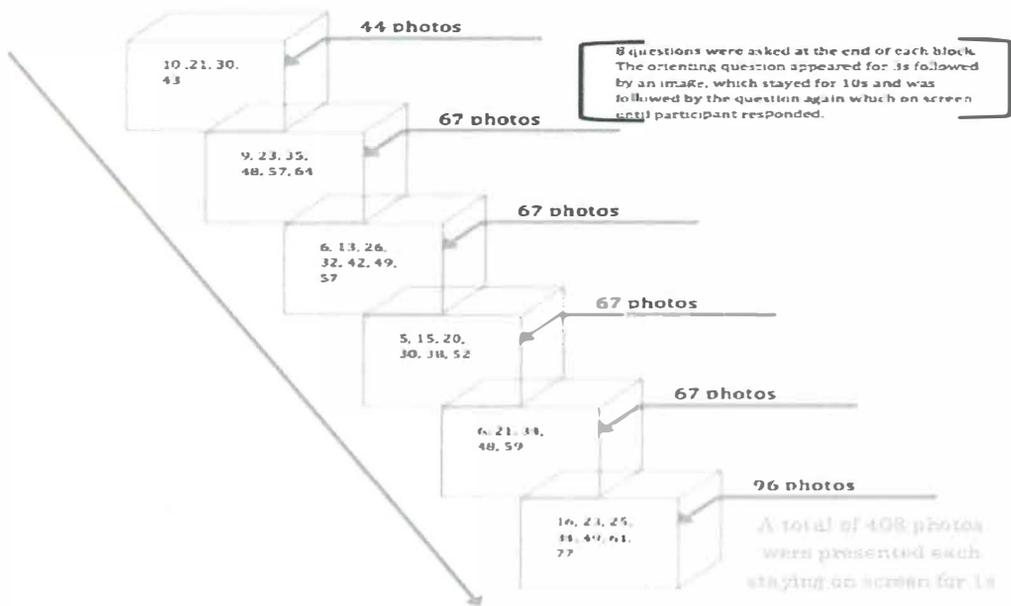


Figure 2.4: *Manipulating Affect According to Groups*. Participants are presented with 20 images, which stay on screen for 2s each, presented at 500ms intervals. This presentation was used as way of manipulating emotional arousal.

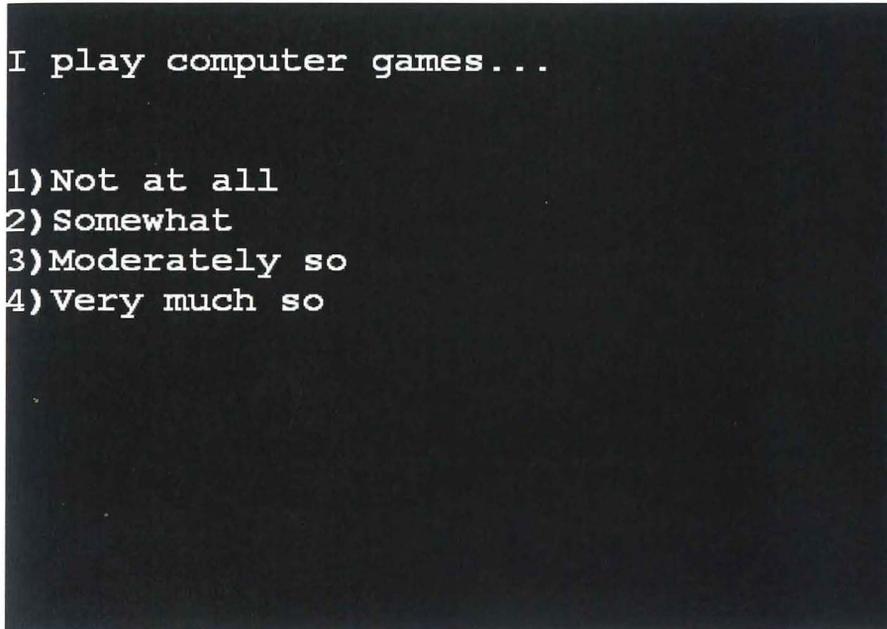
21. Instructions for the main task came on screen reading: *“You are a soldier and you are working in a remote control room. You are asked to monitor the images that are being streamed from a camera. The camera is mounted on a soldier who is currently engaged in fierce fighting. The images coming from the battlefield are jumpy and blurry because of a bad connection. The enemy is trying to interfere or break the connection which is why, sometimes, you might see images that are not from the original camera. Your task is to monitor the images and gather as much information about the situation as you can. Military Headquarters will at times ask you for information. Press spacebar when you are ready to continue...”*
22. Upon pressing the spacebar, the main part of the experiment simulating a war-fighting scenario started. A rapid series of individual slides (408 in all) of a military mission were shown to simulate the scenes during a military

mission. At 6 intervals participants were presented with blocks of eight QASA probes (see attached CD, Chapter 2 for an example of the probes) concerning the situation presented on the previous slides (see Figure 2.5).



*Figure 2.5: Main Experiment Structure.* 6 blocks of photos were presented, the numbers of photos contained are presented on the right side of each block. Between each block of photos 8 QUASA type probes were presented to participants where they had to answer with either True or False. The question was first presented on the screen for 3s. Then, a content relevant photo selected from the just presented block of photos followed by the question again with the option to answer True or False followed it. Following that, a confidence rating from 1 to 4 on participant's answer was taken. The numbers inside the each box indicate the precise position of each of the emotional images presented within each block. Their positions were pseudo randomly assigned to ensure a distribution of emotional images across the whole task but in a non-predictive manner.

23. Upon completing the main task, participants again completed the SAI questionnaire (steps 11 to 15).
24. A final question appeared asking the participants to indicate in a 1 to 4 Likert scale how much they played computer games (Figure 2.6).
25. Debriefing.



*Figure 2.6: Computer Question.* Computer Question assessing participants' familiarity with computer games as participants see it.

## 2.2.2. Results

### 2.2.2.1 Changes in Induced Affect

To assess the effects of the negative, positive and neutral IAPS images on participants, changes in affect were assessed using the State Anxiety Inventory (SAI) subset of the Spielberger State/Trait Anxiety Inventory, one of the most widely used measures of anxiety (Spielberger, 1989). The test was administered before the start of the experiment, and again at the end. The mean differences for the three-affect conditions are shown in Graph 2.1. A one-way between-participants analysis of variance (ANOVA) was conducted on the data with affect condition as the independent variable, and the difference between the post- and pre-test scores as the dependent

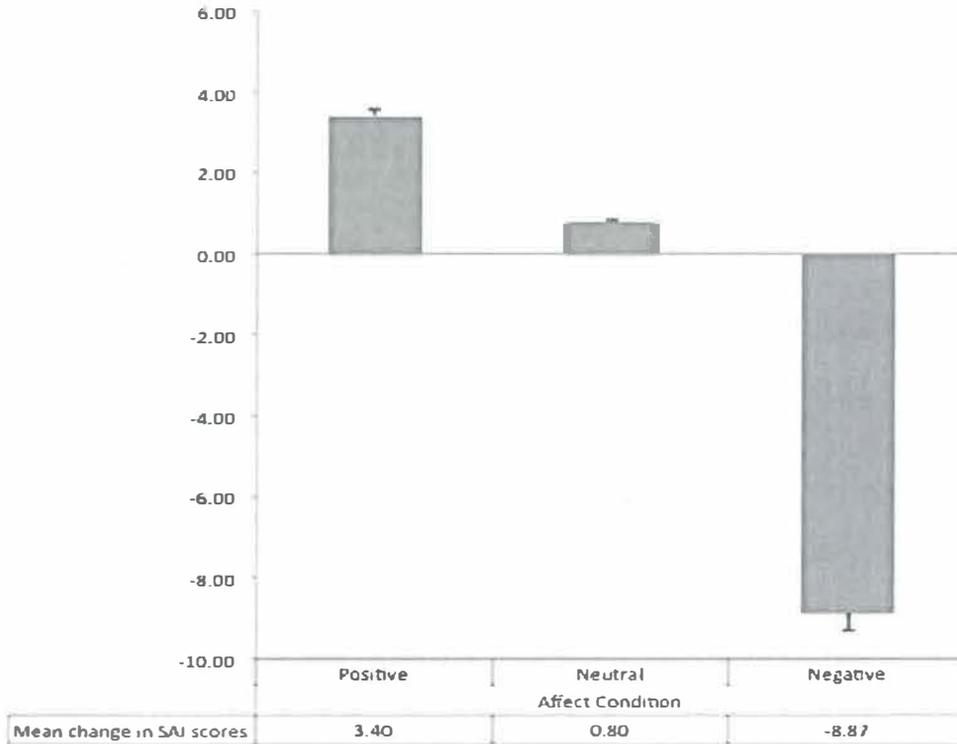
variable; thus a positive score indicates an decrease in anxiety levels, a negative score a increase and a zero score indicates no change.

Using Boxplots, two outliers were detected, one in the negative and one in the neutral group. The outliers were replaced with the value closest to the outlier, which is a method known as “Windsorizing” (Barnet & Lewis, 1978<sup>1</sup>). The bias score was normally distributed for the positive, negative and neutral groups, as assessed by Shapiro-Wilk's test ( $p > 0.05$ ). Homogeneity of variances was violated, as assessed by Levene's Test of Homogeneity of Variance ( $p < 0.05$ ). Anxiety score was statistically significantly different between different affect condition groups, Welch's  $F(2, 26.11) = 21.81, p < 0.01$ . Anxiety score increased from the negative group ( $M = -8.87, SD = 4.03$ ) to the neutral ( $M = 0.80, SD = 5.37$ ) and positive ( $M = 3.40, SD = 8.61$ ) in that order. As Levene's test of equality of error variances was approaching significance ( $p = 0.057$ ), Games-Howell post-hoc pairwise comparisons were conducted. Games-Howell post-hoc analysis revealed that the mean increase from neutral to negative (-9.67, 95% CI [-13.98, -5.36]) was statistically significant ( $p < 0.01$ ), as well as the increase from negative to positive (-12.27, 95% CI [-18.48, -6.05],  $p < 0.01$ ). No significant differences were found between the positive and neutral affect groups in anxiety levels thus confirming that, relative to each other, positive and negative affect conditions resulted in driving the anxiety levels in the expected direction – decreasing for the positive group and increasing for the negative group relative to each other. Only the negative affect condition resulted in a significant increase in anxiety as

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<sup>1</sup> “Windsorizing” (Barnet & Lewis, 1978) will be conducted on all data screening henceforth to account for the influence of outliers. In this process, outlier effect size values are altered to match the next highest, non-outlier, effect size and then the overall mean effect size is recalculated.

compared to the neutral condition; the positive affect, though heading in the expected direction, did not reach significance.



*Graph 2.1 - Mean Change in SAI Scores.*

Error bars indicate the 95% confidence interval for the mean. Mean change in SAI score over the course of the experiment for each affect condition.

#### *2.2.2.2 Testing Differences in Computer Games Familiarity Between the Three Affective Groups*

Due to the presence of many outliers (three outliers were detected in the positive affect condition, one in the neutral affect condition and five in the negative affect condition – all five in the negative affect condition were extreme outliers) and the Shapiro-Wilk test showing that the data were not normally distributed for any of the Groups ( $p < 0.05$ ), a non-parametric counterpart of ANOVA, Kruskal-Wallis test, was run to determine if there were differences in the Computer Games score between

different Emotional Arousal groups. Pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Statistical significance was accepted at the  $p < 0.05$  levels for the omnibus test and  $p < 0.01$  levels for the multiple comparisons. Computer Games score was not statistically significantly different between the different levels of Emotional Arousal. Thus it is concluded that familiarity to computer games, which the task does approximate to an extent and which could have been a potential confounding factor, is not significantly different across the different affective conditions hence unlikely to have acted as a confound.

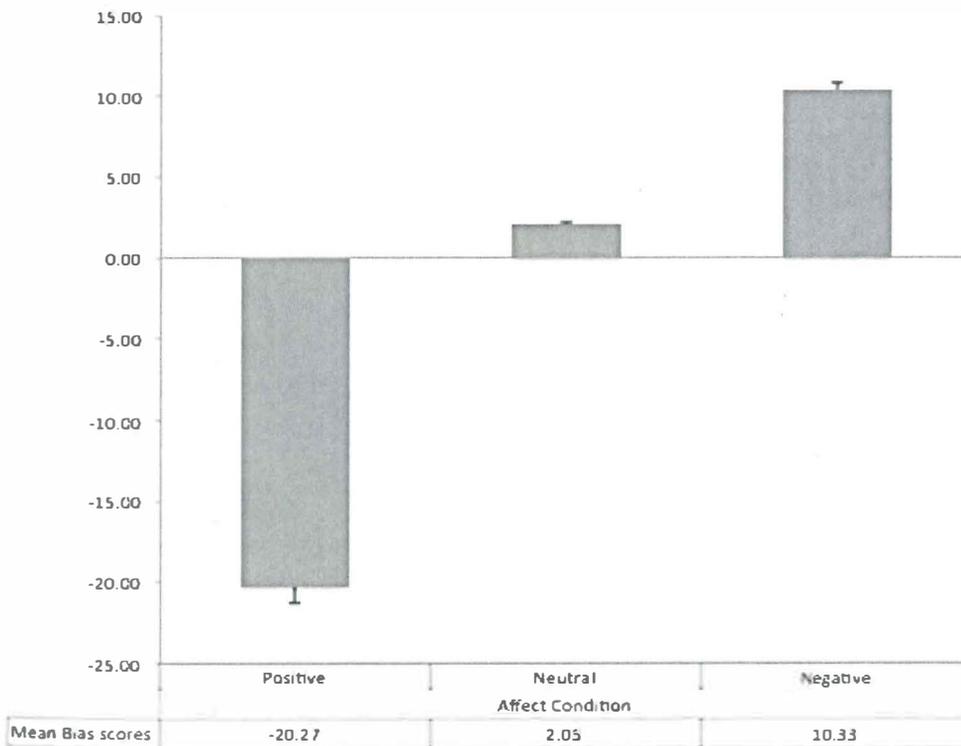
### *2.2.2.3 Testing Experimental Hypothesis 1*

Negative and Positive emotional conditions affect IB differently with the negative affect condition making IB more positive and the positive affect condition making IB more Negative on the QASA scale.

The bias scores were subjected to a one-way ANOVA taking the affect condition (positive, negative and neutral) as the between-participants IV and the calculated bias scores as the DV.

Using Boxplots, two outliers were detected, one in the positive and one in the neutral group. The outliers were replaced with the value closest to the outlier. The bias score was normally distributed for the positive, negative and neutral groups, as assessed by Shapiro-Wilk's test ( $p > 0.05$ ). There was homogeneity of variances, as assessed by Levene's Test of Homogeneity of Variance ( $p > 0.05$ ). The bias score was statistically significantly different between different affect conditions,  $F(2,44) = 51.64$ ,  $p < 0.01$ ,  $\omega^2 = 0.69$ . The bias score increased (see Graph 2.2) from the positive group ( $M = -20.27$ ,  $SD = 11.82$ ) to the neutral ( $M = 2.05$ ,  $SD = 5.91$ ) and negative ( $M =$

10.33,  $SD = 6.61$ ) in that order. Tukey *post-hoc* analysis revealed that the mean increase of bias from positive to neutral (22.32, 95% CI [14.75, 29.88]) was statistically significant ( $p < 0.01$ ), as well as the increase from neutral to negative (8.29, 95% CI [0.72, 15.85],  $p < 0.03$ ) and the increase from positive to negative affect condition (30.60, 95% CI [23.03, 38.17],  $p < 0.01$ ), thus rejecting the null hypothesis.



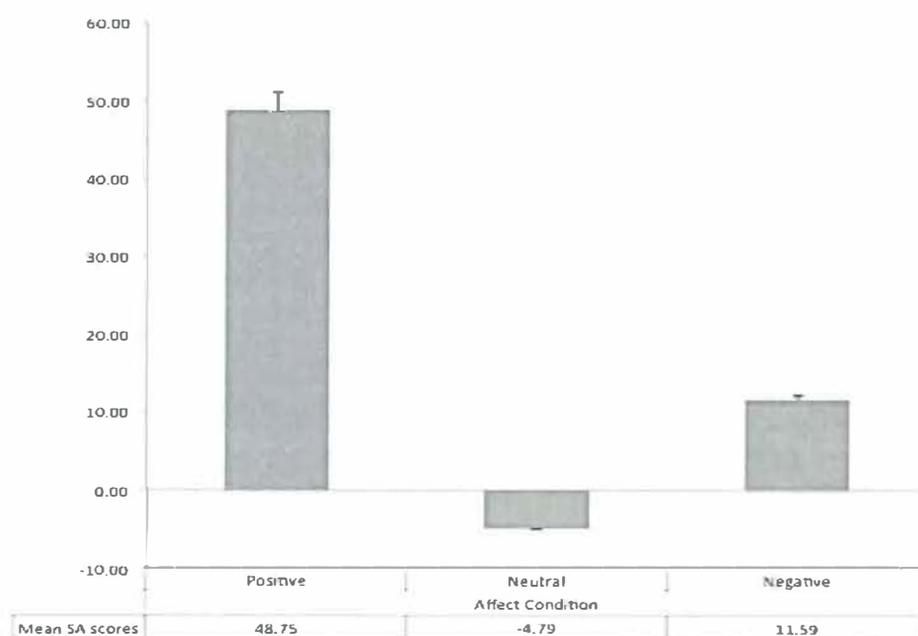
*Graph 2.2: Affective Conditions and IB.* Error bars set at 95% confidence interval. Mean differences on the measures of bias are significantly different between positive and neutral, neutral and negative and positive and negatives affect conditions.

#### 2.2.2.4 Testing Experimental Hypothesis 2

Negative and Positive emotional conditions affect SA differently with Negative condition impairing SA and Positive condition aiding SA score. *Null hypothesis:* Emotional arousal does not affect SA score.

The SA scores were subjected to a one-way ANOVA taking the affect condition (positive, negative and neutral) as the between-participants IV and the calculated SA scores as the DV.

Using Boxplots one outlier was detected in the positive one group. The outlier was replaced with the value closest to the outlier. The bias score was normally distributed for the positive, negative and neutral groups, as assessed by Shapiro-Wilk's test ( $p > 0.05$ ). There was homogeneity of variances as assessed by Levene's Test of Homogeneity of Variance ( $p > 0.05$ ). The SA score was statistically significantly different between different affect conditions,  $F(2,44) = 16.31$ ,  $p < 0.01$ ,  $\omega^2 = 0.39$ . The SA score increased (see Graph 2.3) from the neutral group ( $M = -4.79$ ,  $SD = 28.62$ ) to the negative ( $M = 11.59$ ,  $SD = 28.40$ ) and positive ( $M = 48.75$ ,  $SD = 21.23$ ) in that order.



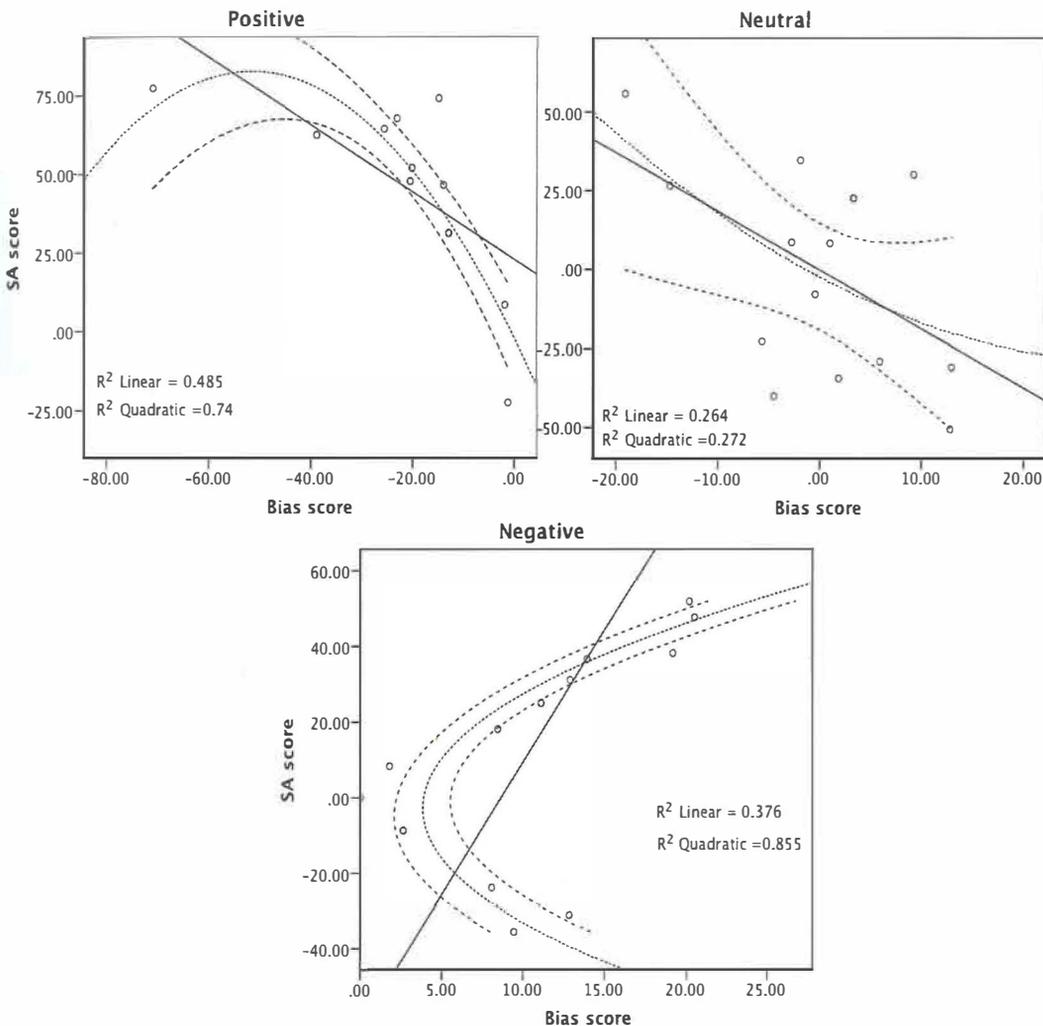
*Graph 2.3: Affective Conditions and SA.* Error bars set at 95% confidence interval. Mean differences on the measures of SA are significantly different between positive and neutral, neutral and negative and positive and negatives affect conditions.

Tukey *post-hoc* analysis revealed that the mean increase of SA from neutral to positive (53.54, 95% CI [30.20, 76.88]) was statistically significant ( $p < .001$ ), as well

as the increase from negative to positive (37.16, 95% CI [13.82, 60.50],  $p < 0.01$ ). There were no significant differences on SA scores between negative and neutral affect conditions ( $p > 0.05$ ), thus the null hypothesis will be rejected.

### 2.2.2.5 Testing Experimental Hypothesis 3

Negative and Positive emotional conditions will affect the relationship between IB and SA. *Null hypothesis*: Emotional arousal does not affect the relationship between IB and SA.



Graph 2.4: *Affective Conditions and Correlation of SA and IB*. SA scores plotted against bias scores for the positive, neutral and negative affect conditions. Linear (solid line) and quadratic (broken line) least-squares line fits are shown. Mean 95% confidence intervals are shown for the quadratic fits.

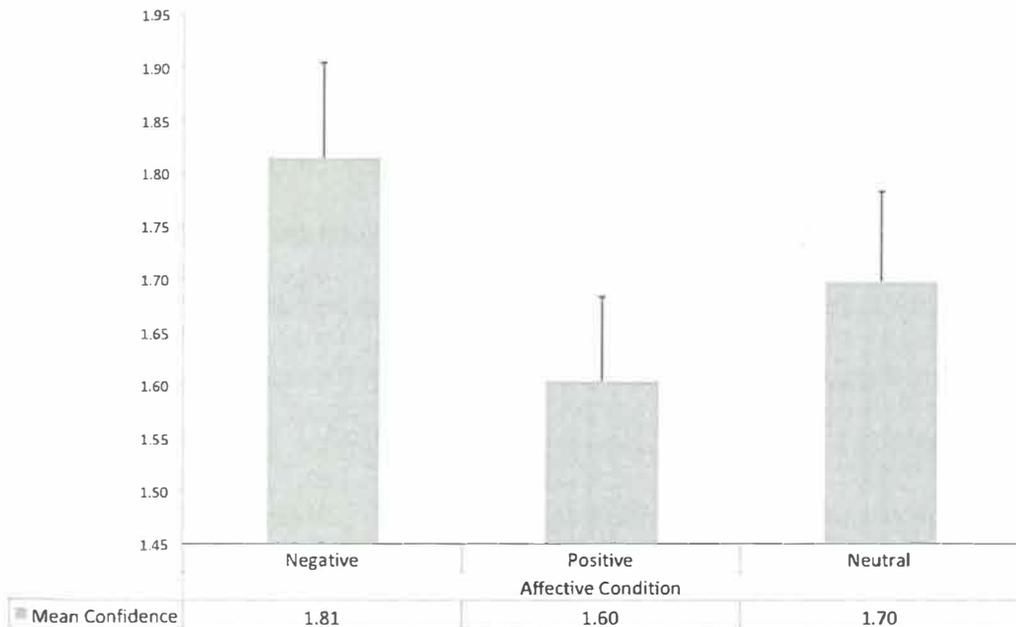
The SA scores were plotted against the bias scores for each affect condition (Graph 2.4). A least-squares procedure was used to fit curves to the data, with a quadratic function providing the best fit. The model was a significant fit of the data in the negative ( $R^2 = 0.85$ ;  $F(1,12) = 35.46$ ,  $p < 0.01$ ) and positive ( $R^2 = 0.74$ ;  $F(1,12) = 17.03$ ,  $p < 0.01$ ) conditions, but not in the neutral condition ( $R^2 = 0.27$ ;  $F(1,12) = 2.24$ ,  $p > 0.5$ ). There was no relationship apparent between confidence and either bias or SA in any of the affect conditions. The maximum  $R^2$  for any plot of confidence against bias or SA was 0.18, and so no further analyses were conducted on these relationships. The curve fits suggest that the relationship between SA and bias is different in different affect conditions and so the null hypothesis can be rejected.

#### *2.2.2.6 Testing Differences in Confidence in Answers Between the Three Groups*

The confidence scores were subjected to a one-way ANOVA taking the affect condition (positive, negative and neutral) as the between-participants IV and the calculated confidence scores as the DV. Confidence scores were added than averaged for each participant hence a score approaching four indicates high confidence whereas a score approaching one indicates low confidence.

Using Boxplots, two outliers were detected, one in the positive and one in the neutral group. The outliers were replaced with the value closest to the outlier. The bias score was normally distributed for the positive, negative and neutral groups, as assessed by Shapiro-Wilk's test ( $p > 0.05$ ). There was homogeneity of variances, as assessed by Levene's Test of Homogeneity of Variance ( $p > 0.05$ ). The confidence score was statistically significantly different between different affect conditions,

$F(2,44) = 11.82, p < 0.01, \omega^2 = 0.31$ . The SA score increased (see Graph 2.5) from the positive group ( $M = 1.60, SD = 0.10$ ) to the neutral ( $M = 1.70, SD = 0.09$ ) and negative ( $M = 1.81, SD = 0.16$ ) in that order. Tukey *post-hoc* analysis revealed that the mean increase of confidence from negative to neutral (0.12, 95% CI [0.01, 0.20]) was statistically significant ( $p < 0.03$ ), as well as the increase from positive to negative (0.21, 95% CI [0.11, 0.32],  $p < 0.01$ ). There were no significant differences on confidence scores between positive and neutral affect conditions ( $p > 0.05$ ).



*Graph 2.5: Affective Conditions and Confidence.* Error bars set at 95% CI interval. Participants in the Negative condition showed the highest increase in the confidence scores, which reached statistical significance. Significant increase in confidence scores for the negative group may reflect this group's attempt to counteract the negative emotions.

### 2.2.3 Discussion

Before discussing the main results, the two control measures indicating familiarity to computer games and the effect of the IAPS images on participants' anxiety levels, as indicated by SAI, will be discussed. The analysis of the two measures that controlled

for the participants' familiarity to computer games and the effect that IAPS images on participants confirmed that there were no significant differences on the former and the expected differences on the latter, both of which were the desired outcomes. The SAI scores, which provide an introspective index of state anxiety at a particular point in time, showed an increase on the anxiety levels for the participants that were shown the negative images. The images, which were selected from the lower end (negative) of the normative valence ratings given by IAPS did have the effect of increasing anxiety levels relative to both the neutral and positive IAPS images. Conversely, the positive images, which were selected from the higher end (positive) of IAPS valence scale led to a decrease in anxiety levels, significantly different from the negative images but not from the neutral images. The analysis of the SAI and the game familiarity scores indicate, therefore, that computer game familiarity was not significantly different across different affect conditions and unlikely to have had an effect on participants' performance, and also that IAPS images did achieved the desired emotional manipulation in the three groups.

Under these conditions, both the bias and the SA scores, as well as their relationship appear to confirm the experimental hypotheses. The bias score was positive for the negative affect condition and negative for the positive affect condition and the analysis showed that the IB for the negative and the positive affects conditions were significantly different from the IB in the neutral affect condition. This is in line with most of the research on attention and emotions presented in the introduction (Friedman & Forster 2010; Fredrickson & Branigan 2005; Kohn 1954). As these studies suggest, under the negative and positive affect conditions, the attentional spans narrows or widens respectively and this seems to have been reflected

by the IB measure of QASA, which became more positive (conservative) in negative emotional conditions, and more negative (liberal) under positive emotional conditions. The analysis of SA scores also confirmed the experimental hypothesis and is also in line with the studies cited in the introduction (Hulse & Memon 2006, 2007; Fredrickson & Branigan 2005). The SA score was improved for the positive affective condition relative to the neutral and the negative affective conditions. The positive affective condition seems to have had a stronger effect on the SA score and significantly improved the SA of the participants.

Importantly, the different affect conditions seem to have had the effect of changing the relationship between the IB and SA scores. Negative affect seems to lead to a general positive shift in bias, which suggests an increase in the rejection of information. As participants' behaviour becomes more conservative and their attention span narrows, this is reflected in a decrease on their overall awareness. However, if they reject the right information (not relevant to SA) they get high SA, if they reject the wrong information they get low, or negative, SA - hence the 'sideways-U' function. These data thus indicate that high positive bias can give either high or low SA. This relationship would suggest that bias is driving SA. This would seem likely, as the absence of feedback in the task (as to whether the answers to the probes are correct or incorrect) would make it difficult for participants to modify their bias in the light of their performance.

If affective state affects bias and bias affects SA, then it would seem likely that in the neutral affect condition there should be a weaker relationship between bias and SA, as was found to be the case. Without the manipulation of affect, bias may show a tendency to freewheel and to drift towards zero (note the bias scores are

generally lower in this condition), leading to no significant relationship between bias and SA.

Positive affect, on the other hand, leads to a negative shift in bias and an increase in the amount of information taken in. That seems to lead to an increase in SA up to a point and then SA appears to level off. An explanation is that SA may plateau when the participant simply cannot handle any more information reaching, in effect, information-processing capacity.

Thus, as hypothesized, the data showed that different affective states did affect SA and IB as well as the relationship between the SA and IB.

It has been shown in this chapter that task-independent emotional arousal does affect SA, IB and the relationship between the two. The next chapter considers what would happen if the emotional stimuli were task relevant. What if the emotional arousal is directly related to task performance? The next chapter provides an overview of emotional theories; beginning with a general overview of psychological and biological models of emotion and narrowing down to focus on the theories and models that have been developed within the context of decision-making and perception.

## Chapter 3 - Emotion and Cognition

*“The Emotions are all those feelings that so change men as to affect their judgments, and that are also attended by pain or pleasure”* (Aristotle, Rhetoric 1378a, 20 - 22)

### 3.1 INTRODUCTION

As demonstrated in the second chapter, emotions do play a critical role in the processes of memory and attention, which are important to Situation Awareness. This finding warrants a closer look at the nature and workings of emotions, which so far have not been considered in the SA context even though the evidence suggest that they are an important aspect of understanding SA.

What are emotions? For most people emotions are a mix of feelings and behaviours, love, hate, disgust, joy, shame, envy, guilt, anxiety, fear and so on are all types of emotions which everyone is familiar with or has experienced at one time or another; they are part of everyday existence. However, questions such as what precisely defines emotions, do they emerge from diffuse or localised patterns of cerebral activity or are they sensory signals arising from the body or even are they something else completely, have proven difficult to answer despite the prolonged interest in their understanding. Aristotle is quoted to have stated in his work, Rhetoric (1378a, 20 - 22), *“The Emotions are all those feelings that so change men as to affect their judgments, and that are also attended by pain or pleasure”*. Building on Aristotle’s work, Galen, a prominent Roman physician, argued for a clear separation between the thoughts and emotions. According to Galen the brain was the seat of reason whereas the heart that of emotion (Galeni,1528, book VI). This view

dominated western thought for over 1000 years until the early 20<sup>th</sup> century when studying the brain's neural circuits opened a new direction in the study of emotions (LeDoux, 2003).

In his 2003 paper on the 'emotional brain, fear and amygdala' LeDoux also charts developments in the neuroscience of emotions in the early part of the 20<sup>th</sup> century. As the discovered link between the hypothalamus and the autonomic nervous system became clearer (Karplus & Kreidl, 1927), it was proposed that the hypothalamus also played a central role in emotional processing (Cannon & Britton, 1925). Papez (1937) and MacLean (1949, 1952) retained the link between the hypothalamus and the autonomic nervous system and extended it to include the forebrain in the emotional circuits; later on christened as the limbic system. The term limbic system is still in use (Nakano, 2007) but, as LeDoux (2003) points out, there is no clear definition guiding the selection of structures of the brain that should be included (or excluded) from that system, and the current definition has not fostered wide acceptance among researchers. Nonetheless and as it will be discussed further in this chapter, the early research on the brain circuits underlying emotions, especially the limbic system has been and continues to be the basis for many of the theories of emotions today. The trend in the research on emotions, however, has been somewhat sporadic and not consistent.

Despite the long historical interest on the topic and the potential benefits that knowledge about emotions would certainly afford, there has never been a systematic, rigorous and sustained approach on the study of emotions. The reasons why may be glimpsed from a statement taken from Gardner (1985, p.6) who, while fully acknowledging the importance of emotions for cognitive functioning, states that their inclusion would "*unnecessarily complicate the cognitive-scientific enterprise*".

Evidently not many researchers have agreed with Gardner's proposition. For example, LeDoux (2000) states: "*A pure cognitive approach, one that omits consideration of emotions, motivations, and the like, paints an artificial, highly unrealistic view of real minds. Minds are not either cognitive or emotional, they are both, and more. Inclusion of work on emotion within the cognitive framework can help rescue this field from its sterile approach to the mind as an information-processing device that lacks goals, strivings, desires, fears, and hopes*". Furthermore, as evidence for the growing interest in this field, Murray, O'Doherty & Schoenbaum (2007) cite an interesting statistic, in 1987, two years after Gardner's statement, only nine papers were published with the term Orbitofrontal Cortex, an area implicated in emotional processing, by 2007 this had increased to an average of 32 papers per month.

The complexity notwithstanding, an ever-increasing body of research on emotions has accumulated over the years, a small portion of which was discussed in Chapter 2. This chapter will investigate further the theory and research on emotions with particular focus on the biological perspective. This chapter is divided into two main sections.

The first section can be further divided into three general sub-sections the first of which will chart the most prominent developments in the investigation of emotions, past and present. It will be argued that emotions and feelings are not external to the functioning of cognition but are rather part and parcel of it. It is unlikely that the capability to reason has evolved independently of the mechanisms of biological regulation and the latter are inextricably linked to emotional and motivational forces which are fundamental processes of survival and adaptation (Damasio, 1994; Ekman & Davidson, 1994; Pinker, 1997). It will be shown that evidence from neuroscience

and other related disciplines suggests an important role in the regulation of positive and negative affect for the prefrontal cortex (PFC) and Amygdala both of which are highly interconnected into larger circuits including the anterior cingulate, hippocampus, and insula (Davidson, Putnam & Larson, 2000b).

The second sub-section will evaluate the neurological basis of this view and suggest that the representations of the body proper in the somatosensory maps and other related neural circuits might fundamentally underpin the ontology of emotions. It will be argued that increasing evidence supports the proposition that emotional states are, if not entirely, at least in part representations of various states of the body in the Central Nervous System (Damasio, 1994).

The third subsection will present the case for clear functional links between the autonomic nervous system, operations of emotions and their modulating effects in cognitive functions of attention, memory and learning. A more specific aim of the third sub-section is to argue that emotional processes are not simply adjunct to other cognitive processes to be studied as an afterthought, much like Gardner above seems to suggest, but are rather inseparable and that a complete account of any cognitive process must necessarily account for emotions.

The second main section will examine the experimental evidence from the stance of psychological and biological perspectives with particular focus on the Somatic Marker Hypothesis (SM). First outlined by the neuroscientist Antonio Damasio and colleagues in 1991 (Damasio, Tranel & Damasio, 1991) and later on described on much greater detail in his book, *Descartes Error* (Damasio, 1994), the Somatic Marker Hypothesis argues for an important role of emotions in decision-making processes. According to Damasio (1994), the Somatic Markers, so called because of their origin in the body proper and the Autonomic Nervous System (ANS),

are responsible for bringing to bear in decision making processes, prior experiences whose affective component can bias decisions towards those that, in the past, have been associated with positive outcomes and away from those that have been associated with negative outcomes. The examination of Damasio's and other researcher's work in this area will lead to a number of hypotheses, which will be tested in a series of experiments that follows.

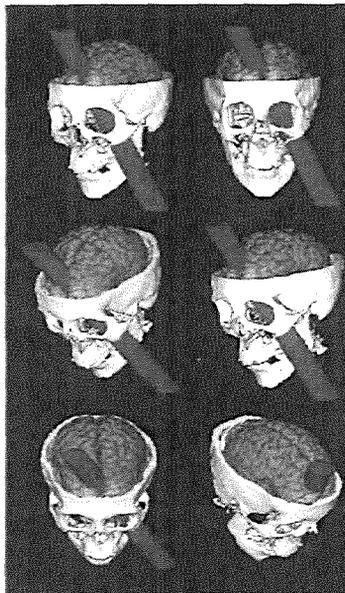
### *3.1.2) Phineas Gage's Accident Marks a Change in our Understanding and Investigation of Emotions*



*Figure 3.1 Photo of Phineas Gage.* This is a photo of Phineas Gage holding the iron that destroyed his frontal lobes.

Phineas Gage (Figure 3.1) is perhaps one of the most familiar names to any researcher of neuroscience, novice or experienced. The interested reader is directed to the first Chapter in Damasio's book "Descartes Error". It offers a detailed account including a cursory analysis of the reactions of the neuroscientist of the time (Damasio 1994, p. 3).

Although the precise details of Gage's story and the subsequent explanations are not entirely agreed upon (see for example Macmillan 2008), it is generally undisputed that the lesions on specific areas of the frontal lobes caused the peculiar changes to Gage's cognitive functioning. Unfortunately there was no post-mortem done on Gage's brain hence the exact location of the damage is not known. However, a reconstruction of Gage's skull and iron rod in three dimensions has allowed researchers at Harvard Medical School to conclude that the damage that Gage sustained was most likely confined to the left pre-frontal cortices including Ventr-Medial Prefrontal Cortex (vmPFC) region of the brain (Damasio, 1994, p. 31-32) (Figure 3.2).



*Figure 3.2: The reconstruction of Gage's skull and iron in three dimensions.*

A particularly intriguing observation following Gage's injury was the apparent intactness of his logic and rational thinking standing in stark contrast with the glaring deficiencies in his global functioning (Damasio, 1994), which brings into question purely rational models of decision making. Experimental investigations of decision-

making have shown that, much like Gage's functioning after his damage to vmPFC demonstrates, real life decision making under varied degrees of uncertainty do not describe an exclusively rational mind (Haidt, 2001; Green, 2009; Damasio, 1994, 2004). The distinction between the rational and the, so to speak, emotional functioning is a fundamental tenet of the dual process theories of cognition who argue for the co-existence of two systems, System II (analytic) and I (heuristic) respectively (Gawronski & Bodenhausen, 2006; Kahneman 2011, p. 19). The case of Gage's post accident selective deterioration of emotionally based cognitive functions while maintaining the capability to reason rationally seems to support the view of two, relatively separate cognitive systems.

### 3.1.3 EVR - *The Modern Gage*

In 1991, Damasio and colleagues reported a case study involving a patient, codenamed EVR, with brain damage in the frontal lobes in the same general area as Gage's. EVR was around 35 years of age when he had to undergo brain surgery removing a meningioma. The operation left him with bilateral lesions on ventromedial frontal cortices. Prior to the operation EVR is described as "*from all perspectives a normal individual. He was intelligent, hard working, successful at securing a steady skilled job, and at being promoted for his good performance. He was active in social affairs and was perceived as a leader and example by his siblings, and by others in his community*" (Damasio, Tranel & Damasio, 1991 p. 217). Following the surgery, just like Gage, EVR could not maintain a job and his ability to plan his immediate and future activities was severely impaired. A typical feature of EVR's post operation functioning was to engage in endless deliberation of multiple choices ending up, if at all, selecting a random choice.

It is important to highlight that despite the severe impairments that were plain for everyone to see and have been documented (Damasio et al., 1991, p. 217-218), just like Gage, EVR's other cognitive processes remained undisturbed. A battery of neuropsychological tests indicated that EVR's intelligence functioning remained intact or ranking on the higher end of the scales. EVR's IQ scores on the Wechsler Adult Intelligence Test-Revised were within the top 1st-2nd percentile. A range of other neuropsychological tests also indicated a high functioning individual: Shipley-Hartford Vocabulary score = 37/40; Abstraction score = 40/40; Visual-Verbal Test score = 73/84. In addition, EVR also showed a normal to superior ability in tests of learning and memory, scoring 145 in Wechsler Memory Scale, 14 out of 15 in Rey Auditory-Verbal Learning Test Trial 5, 9/10 in Benton Visual retention Test and 32/36 in Ray-Osterrieth Complex Figure recall score (Damasio et al., 1991, p. 218). And finally, according to Damasio, EVR's performance in Wisconsin Card Sorting Test, the Category Test, the Word Fluency test and paradigms requiring cognitive estimation and judgments of regency and frequency were perfect. It would be hard to argue that anyone looking at the range of tests and the scores produced by EVR would get any hint at all that they indicated a damaged mind. Classical tests of memory, learning and attention, such as the comprehensive range cited above, seem to be completely insensitive to EVR's condition. It is worth pointing out that the failure of these tests to detect anything raises some important concerns for the validity of SAGAT, which is essentially based in similar measures of memory, attention and learning.

A critical point in understanding EVR's condition, Damasio suggests, is to consider the basis of the mind as relying on the synchronized activity of multiple brain regions in which vmPFC has an important role. In his earlier paper (Damasio,

1989) argues against the integration of memory and motor processes in single, defined anatomical locations and advocates instead for the time-locked, synchronous activations of multiple sites as a better fit; in this scenario, timing is critical. According to Damasio, meaning emerges by the time-locked multiregional retroactivation of widespread fragment records, the concerted activity of which can become manifest consciousness. He suggests that the recall of entities and events occurs when the neuron ensembles in multiple sensory and first-order association and motor cortices are synchronously activated in time-locked fashion from firings on convergence zone neurons (see Damasio, 1989 for a full review); the latter operate both at prior and later levels of processing. The activity of convergence zones, of which, as we will see vmPFC is an important site, is crucial in that it enables a two-way communication between representations arising directly from the body proper and those residing in the central nervous system.

According to Damasio, the brain representations of an excitatory stimulus are first represented in the early sensory cortices and the somatosensory representations of the body-states, both of which have feedback and feed-forward connections with convergence zones. The latter maintains the order of the onset of the brain activity and also brings to bear the attentional focus via the feedback connections to the early somatosensory and other sensory cortices. The systems are locked into a brief, synchronous activity, which spans across cortical and sub-cortical structures (Damasio, 1994, p. 162). In cognitive terms, this means holding on-line multiple bits of heterogeneous cognitions while they are evaluated for their negative or positive consequences. In this scenario, and largely in line with Panksepp's description of a State versus Channel model (Panksepp, 2004, 2007) as well as Kahneman's System I versus System II functioning (see sections 3.1.4.2 and 3.1.5 below, respectively), the

Somatic Marker (SM) may involve non-specific neurotransmitter systems, like dopamine or serotonin, which can bias the activity in the cerebral cortex towards aversive or appetitive behaviours. Damasio argues that the SM system is an expression of the large available pool of experiences acquired via the punishment/reward feedback mechanisms. The function of this mechanism, Damasio argues, is to restrict the decision space towards a smaller and selective set of choices which are more likely to be relevant in a given a situation and hence increase the speed and efficiency of the decisions made.

A neuroscientist by profession, it is worth pointing out that Damasio's view of the organisation of the brain is largely in accordance with the most recent developments in neuroscience in the way the brain is studied. The Graph Theory and Connectivity studies have shifted the focus of investigation from specific brain regions to identifying areas of high and low neuronal connectivity at the systems and networks level (Bullmore & Sporns, 2009). This approach seeks to categorise the organisation of the brain in terms of network hubs of differing connection densities. Multimodal neuroimaging and neurophysiological studies have found many important and highly densely connected network hubs in the medial frontal and parietal regions (Xie & He, 2011). A consistent finding has been that damage in highly connected network hubs results in more widespread effects and greater damage to the overall cognitive functioning as compared to damage in comparatively less densely connected hubs (He & Evans, 2010; Bullmore & Sporns, 2009). The concept of convergence zones that Damasio proposes can be seen as a pre-cursor to the concept of the brain's network hubs of connectivity. A particularly important and densely connected hub resides in the frontal lobes. In particular, the functioning of the medial prefrontal cortex, part of which is vmPFC, has drawn wide attention especially for its

association with emotional processes and their effect in higher-level cognitive processes of abstract thinking and reasoning (LeDoux, 2003; Bechara, Tranel, Damasio & Damasio, 1996).

#### *3.1.4 Structural and Functional Organization of Prefrontal Cortex*

Since the time of Gage and until now, the functioning of the Frontal Lobes have been a focus of continuing fascination in neuroscience and a great and increasing number of studies are leading to a much more nuanced understanding of their functions. The methods of study have included studying behaviour in patients with brain lesions (Damasio et al., 1991), experimentally producing brain lesions in animals (Kolb & Nonneman 1978; Kolb 1984), stereotaxic surgery (Goldensohn 1992), histological methods (Cooper, Siddons Mann, 1995) and more recently imaging the living brain with various non-invasive modern scanning techniques such as functional Magnetic Resonance Imaging (fMRI), Electroencephalography (EEG), Positron Emission Tomography (PET) and others.

The emerging mosaic of evidence points to a close and complex interaction between, especially, the medial prefrontal cortex and the limbic system, such as the amygdala-hippocampal circuits (LeDoux, 2003, pg. 151), associating, roughly, the higher level cognitive functions with the former and emotional functioning with the latter. The medial prefrontal cortex is regarded by an increasing number of neuroscientist (LeDoux, 2003; Damasio, 1994) as an essential anatomical part of the brain, which allows cognitive processes to regulate and be regulated by the neural circuits of the limbic system, especially amygdala.

As we will see, the medial prefrontal cortex may be the best candidate site where the neuronal systems responsible for the integration of the limbic and cognitive

information. Furthermore, the evidence presented below shows a clear functional link between the pre-frontal cortex and the autonomic nervous system of the body. This is important since one of the main theories considered in this and next three chapters, the Somatic Marker Hypothesis, considers the functioning of the body proper as a central component in the ontology of emotions and assigns to it an influential role within the human decision making processes.

#### *3.1.4.1 Evidence of the Functional Anatomy of the Pre-Frontal Cortex and its Interconnectivity with Subcortical and Autonomic Nervous System Networks*

Compared with other animals, the prefrontal cortex (PFC) is more developed in humans accounting for about 30% of the cerebrum (Fuster, 1996). PFC can be divided into three substructures, lateral, orbital and medial all of which are very densely connected areas. Orbital and medial structures (OFC and MFC respectively) are particularly heavily connected with higher sensory, cortical as well as the limbic and other subcortical areas of the brain associated with emotions (Kahnt, Grueschow & Speck, 2011). Specifically, the lateral OFC is densely connected to the sensory areas of olfactory, gustatory, somatosensory, auditory, visual and also the pre-motor regions (Cavada, Compañy, Tejedor, Cruz-Rizzolo. & Reinoso-Suárez, 2000). MFC is selectively connected with the hippocampus, posterior parahippocampal cortex, posterior cingulate and retrosplenial areas, and area prostriata whereas OFC receives greater inputs from Amygdala. Both, OFC and MFC structures are connected with amygdala, hippocampus, thalamic limbic nuclei, cingulate cortex (Rempel-Clower & Barbas, 1998) and biochemically specific cell groups in the basal forebrain and brainstem (Cavada et al., 2000). Furthermore, both OFC and Amygdala project to the inhibitory thalamic reticular nuclei (Zikopoulos & Barbas, 2006, 2012) which is an

essential brain system implicated in the operation of selective attention (McAlonan, Cavanaugh & Wurtz, 2006; Zikopoulos & Barbas, 2012). The projections of Amygdala and OFC to the inhibitory thalamic reticular nuclei (TRN) can explain the neuronal mechanisms through which emotionally salient stimuli is able to attract attention. Important aspects of this interconnectivity are considered below.

The Amygdala, which has long been known for its involvement in fear, anxiety and other processing of negatively valenced stimuli (Larkin 1997; LeDoux, 1996, 2000), has recently been suggested that it is also involved in the processing of positively valenced stimuli; there is evidence that the latter modulates the activity of the Amygdala to a greater degree than negatively valenced stimuli (Cunningham, Van Bavel & Johnsen, 2008).

On the prefrontal cortex, Kringelbach & Rolls (2004) propose that rewards and punishment related information is processed separately, with the MFC monitoring reward related information whereas lateral OFC monitors punishment related information. A recent fMRI study found evidence for this proposition and, in addition, found evidence that MFC codes both reward related information and their behavioral consequences whereas OFC made use of the negative reinforcement to cue behavioural change (Elliott, Agnew & Deakin, 2010). Kringelbach and Rolls also found that anterior parts of OFC were more related to the processing of abstract stimuli as compared to more posterior OFC areas.

Recently, Kennerley and colleagues have reported a double dissociation between the functioning of OFC and Anterior Cingulate Cortex (ACC) with the latter using a common valuation currency integrating multiple decision parameters and the former dynamically evaluating current choices relative to recent choice values (Kennerley, Behrens & Wallis, 2011).

Left Prefrontal Cortex (LPFC) on the other hand is causally associated with a suboptimal decision strategy, especially in situations requiring greater degrees of cognitive control (Xue, Juan, Chang & Lu, 2012). Controlling for different degrees of uncertainty, Stern, Gonzalez, Welsh & Taylor (2010) found that increased uncertainty during the accumulation of evidence was associated with increased activity in the dorsal anterior cingulate cortex, whereas greater uncertainty associated with the execution of a decision increased activity in the lateral frontal and parietal activity. Also the ventromedial pre frontal cortex (vmPFC – Figure 3.3) did show an increased activation with increased uncertainty. vmPFC receives input from both sensory regions and somatosensory cortices (Rolls, 2004) both of which are interconnected among themselves and have extensive inputs from the body proper (Damasio, 1994, p.180; Bush, Luu & Posner, 2000).

Of particular relevance to the issue of the link between cognition and bodily aspects of emotion, it has been long demonstrated that electrical stimulations of PFC result in significant increases in blood pressure and can provoke an autonomic response strong enough to cause cardiac ischemia and myocardial infarction (Rempel-Clover & Barbas 1998). This suggests a causal neural pathway from PFC to the autonomic structures of the nervous system, possibly via its projections to the hypothalamus. To trace the ascending and descending neuronal projections between prefrontal cortex and hypothalamus, Rempel-Clover and Barbas injected horseradish peroxidase conjugated to wheat germ agglutinin (in 17 animals), fluorescent dyes (in 3 animals) and <sup>3</sup>H-labeled amino acids (4 animals) with eight injections in the OFC, 8 in MFC and 8 in LFC in a total of 24 Rhesus monkeys. The brains of the Rhesus monkeys were then dissected and studied under microscope. Rempel-Clover and Barbas found strong evidence for robust descending neural projection specifically

from the limbic prefrontal areas to the hypothalamic autonomic areas supporting the idea for a structural and functional connection between the prefrontal cortex and autonomic nervous system via the hypothalamus.

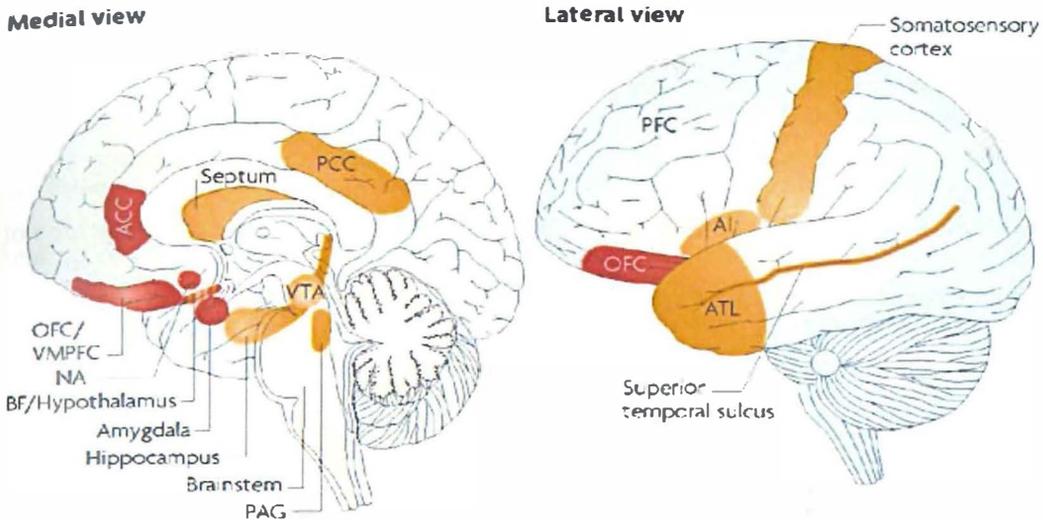


Figure 3.3: Approximate locations of Lateral, Orbital and Medial Pre Frontal cortices on a model of the brain.

#### 3.1.4.2 The Integration of the Pre-Frontal Cortex Within Large Scale Theories of Brain Organisation

Many neuroscientists have attempted to organize this highly complex mosaic of interconnected brain regions into larger psychobiological explanatory constructs with varying degrees of success. The SAS model, which was discussed in the first chapter, is one example. More recently, Panksepp (2004) has suggested that the functioning of the brain is best organised around two major axes, namely State versus Channel functioning. The State functioning denotes the propensity of some brain systems to have a global effect and rely less on sensory channels than is the case for the Channel functioning. These systems involve biogenic amino transmitters, norepinephrine,

dopamine and serotonin systems whose widespread effects are the global regulation of neuronal arousability.

According to Panksepp, these functions may be necessary to generate the psycho-neural context that drives more finely grained cognitive functions. The latter, that constitute the Channel functioning, are more in tune with the stream of information from sensory and perceptual channels, hence are designated as Channel functioning, and respond to pressure created by the State function. Panksepp argues that State or Global functioning differs from channel functioning in that they are not computational in the same way. The State functioning role is not to convey discrete packets of information but create holistic urges and in their evolutionary role - which, according to Panksepp (2004), precedes Channel control systems - have left their imprint in the instinctual behaviours who display intentionality as part of the action apparatus. The comparatively newly developed cortical centres, which underlie channel functions, are more akin to generation of subtler choices.

There is a clear parallel to this neuroscience perspective of the organisation of the brain and the cognitive theory of brain organisation known as the dual process theory (see next section), which also organises cognitive functions along two systems, System I and System II. As will be explained below, the functional description of the State functioning of the brain as described by Panksepp also describes the characteristics of System I functioning, and Channel functioning that of System II. Taken together, both theories amalgamate into a clearer picture of the biological and cognitive aspects of psychological functioning, both of which are needed for a full explanation of the interaction between emotion and cognition. The next sections will focus on the cognitive aspects of emotional organisation.

### *3.1.5 Dual Process Theory of Cognition*

As the circumstances surrounding Gage's accident demonstrates, people are often prone to errors. While fortunately for most of the time the consequences of our errors are negligible, at other times they can be very costly or dangerous indeed (see Chapter 1, e.g. Woodhouse & Woodhouse 1995; Gronlund, Ohrt, Dougherty, Perry & Manning, 1998). Consequently, a large number of public and private entities are interested and invest in finding ways to reduce error occurrence, an apt example is the funding of this research by the MoD. Typically, attempts at reducing the scope for error have resulted on ever more elaborate checklists and procedures (Kahneman 2011). They are certainly effective and serve an essential role in reducing the scope for error in a wide variety of tasks. Well designed checklists and procedures can be effective for tasks such as setting up complicated equipment, handling malfunctions or running regular checks on multiple systems.

However, an important question is how do these checklists and procedures interact with experience and skill? Is the way that people function based on laws of logic and clean powers of deduction which underlie mathematical and cost-benefit type analysis, or are they more likely to base their cognitions in intuition and gut feeling. The answer, as we will see, is both. Which mode of cognition takes priority depends on the situation but both modes of cognition are at play all the time. This is, in a nutshell, what the Dual Process Theory argues for.

The Dual-Process theory argues for the existence of two separate cognitive systems, System I and System II, each encompassing quite distinct evolutionary histories (Evans, 2003). Evans describes System I as evolutionarily old, universal and one that humans share with other animals. System II on the other hand is, comparatively, evolutionarily young; its most obvious manifestation is the distinct

human ability for analytical and abstract reasoning. This distinction, of course, is not new and has resurfaced in various guises in the psychological discourse of at least the past 100 years. In a literature review, Sloman (1996) observed that System I is analogous to the described operations of vast and diffuse associative networks whose *modus operandi* consists of learned associative pathways working in parallel, whereas System II is analogous to descriptions of serial, analytic systems, manipulating symbols in a rule-governed way.

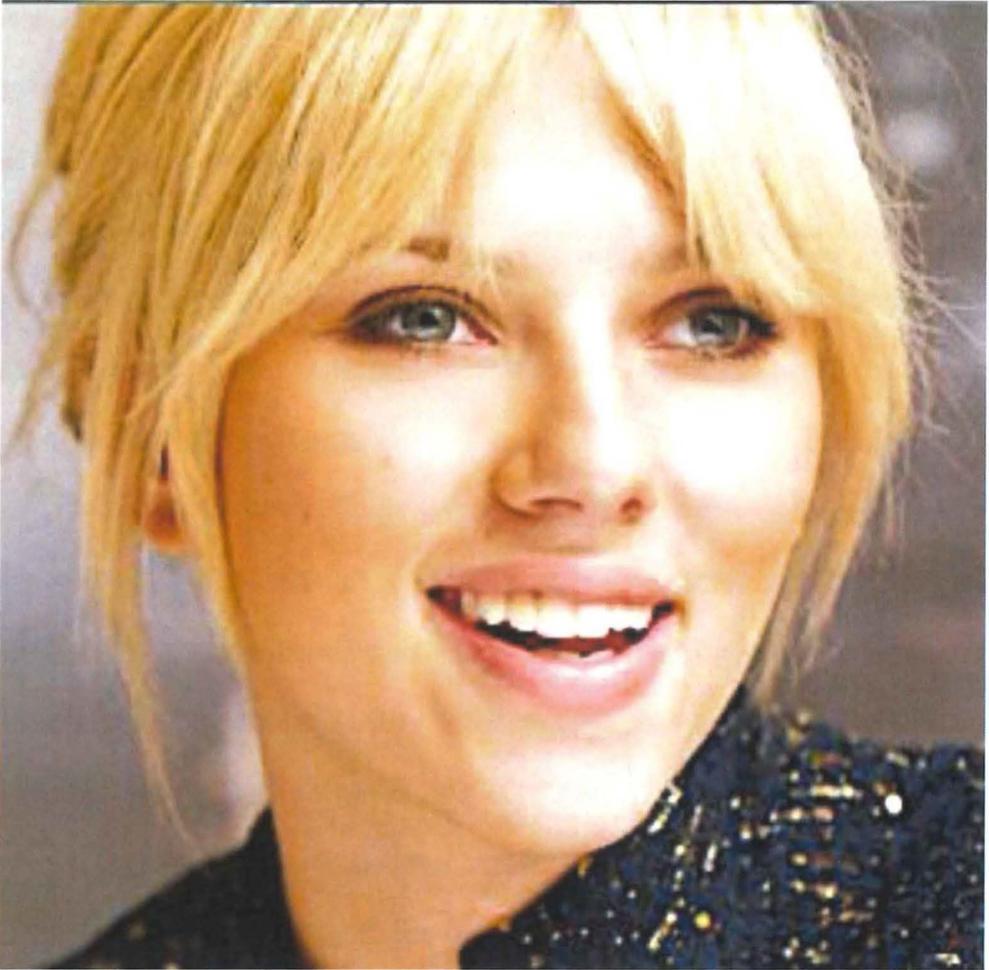
Prominent advocates of the view of cognition as a rule based, analytic system, Fodor & Pylyshyn (1988) have argued that via combinations of simple rules, the mind is capable of generating large numbers of propositions to create ever more elaborate and larger sets of propositions. They highlight that rule-based systems of the mind, branded as the “language of thought”, are systematic in nature. An example they give is that the capability of understanding that “Mary loves John” implies a capability of understanding “John loves Mary”. There is no doubt that we can reason in this way but, Sloman (1996) argues, that is one method of reasoning which functions aside another whose mode of operation is rather different. An example is heuristic reasoning, which is a mode of thinking and decision-making based on intuition and expertise. This mode of thinking is largely automatic, comprised of many subsystems, which run in parallel below the level of consciousness awareness (Ferguson & Zayas 2009). We are aware of only their product which emerges into conscious awareness while the processes themselves remain hidden (Evans, 2003).

Not unlike the SA debate of product versus process, there has been a long debate within psychological circles whether cognition processes information in a serial or parallel way dividing researchers along these lines of explanation. See for example the debate between the Associationists and Gestalt psychologists, the former

arguing that the perception as a whole is built by elementary associations whereas the latter arguing that the whole precedes its parts or Treisman and Gelade's earlier work on the feature integration theory of attention which suggests that features of the visual scene, for example, are registered early, automatically and in parallel while objects are recognised later requiring focused attention (Treisman & Gelade 1980) . Treisman and Gelade asserted that "float free", unattended features of a visual scene can be conjoined by utilizing past experience and contextual information prior to conscious perception.

The dual process theory takes the view that both modes of thinking are present and attempts to integrate them into one overarching explanation. Evidence does seem to support the presence of both systems and suggests important differences in their functional and anatomical characteristics as well as phylogenetic history, which may clarify as well as extend the implications for the effects of emotion on cognition.

For example, look at the picture of the face at Figure 3.4 on the left. Immediately and in parallel, simultaneous fashion one knows that it is of a female, with blonde hair, smiling, happy, and for someone who has seen her movies there will be an associated feeling of familiarity (the picture is of the actress Scarlett Johansson). Both perceptual (blonde, female) and intuitive (happy, familiar face) information emerges seamlessly without any conscious effort. This mode of thinking is clearly not a product of detailed analysis of an analytic system. Conversely, and as any A level student will testify, making sense of a complex mathematical equation does not "jump out" in the same way; a systematic, procedural led, knowledge based analysis is required (Kahneman 2011, p. 19).



*Figure 3.4: System I and System II Functioning.* System I - Looking at the picture above (Actress Scarlett Johansson) one can without much thinking or analysing derive a number of conclusions almost immediately.

A demonstration of differences on the basic cognitive processes along the System I and II functioning can be found in a study by Öhman, Flykt, & Esteves (2001) who reported that participants' search and find behaviour towards fear-relevant pictures (snakes or spiders) but not fear-irrelevant pictures (flowers or mushrooms) was relatively unaffected by stimulus location or the number of distractors. It suggests that fear relevant pictures, which represent an emotional stimuli, are handled by parallel processing whereas non-emotional stimuli are handled

by serial processing; a distinction made in System I and System II functioning respectively.

The processes of System I can greatly affect and usually dominate System II. Using the Sequential Evaluative Priming Paradigm, Fazio, Sanbonmatsu, Powell, & Kardes (1986) have shown that the classification of the valence of the Target stimuli is faster and more accurate when it shares the same valence with the Prime even though the latter is not consciously perceived. This shows that Primes are unconsciously and automatically processed and that they affect the conscious evaluation of the Targets implicitly. This capability of System I to exert covert influence to observable behaviour has been demonstrated for human faces, images of objects and it can affect mood states behaviours and judgments (Ferguson & Zayas 2009).

A particularly elegant, highly ecological demonstration of System I and II functioning and their interaction is illustrated from a study carried out at the University of Newcastle, UK (Bateson, Nettle & Roberts, 2006). They tested the effects of seemingly unrelated stimuli on the participants' behaviour. Capitulating on a long established honesty box system which was used for collecting voluntary payment to pay for coffee and tea, Bateson et al., (2006), introduced an instructions for payment noticeboard which was displayed at eye height on a cupboard door located above a counter on which the honesty box was situated along with the coffee and tea making equipment. The notice featured a 150 by 35 mm banner that alternated each week between an image of a pair of eyes and an image of flowers printed above the prices for tea, coffee and milk. Keeping participants naive to the purpose of the banner, researchers recorded every week the total amount of money collected in the honesty box and computed the ratio of money collected to the volume of milk

consumed in each week to control for weekly variation in consumption (Figure 3.5). The graphed results are self-evident and show rather clearly how an apparently unrelated stimulus did influence behaviour. If asked, the participants who were completely unaware of the banner would surely not be able to make the link between their behavior and the banner. How would current SA models cope with this given that the main causal factor of this behaviour is not consciously linked to it?

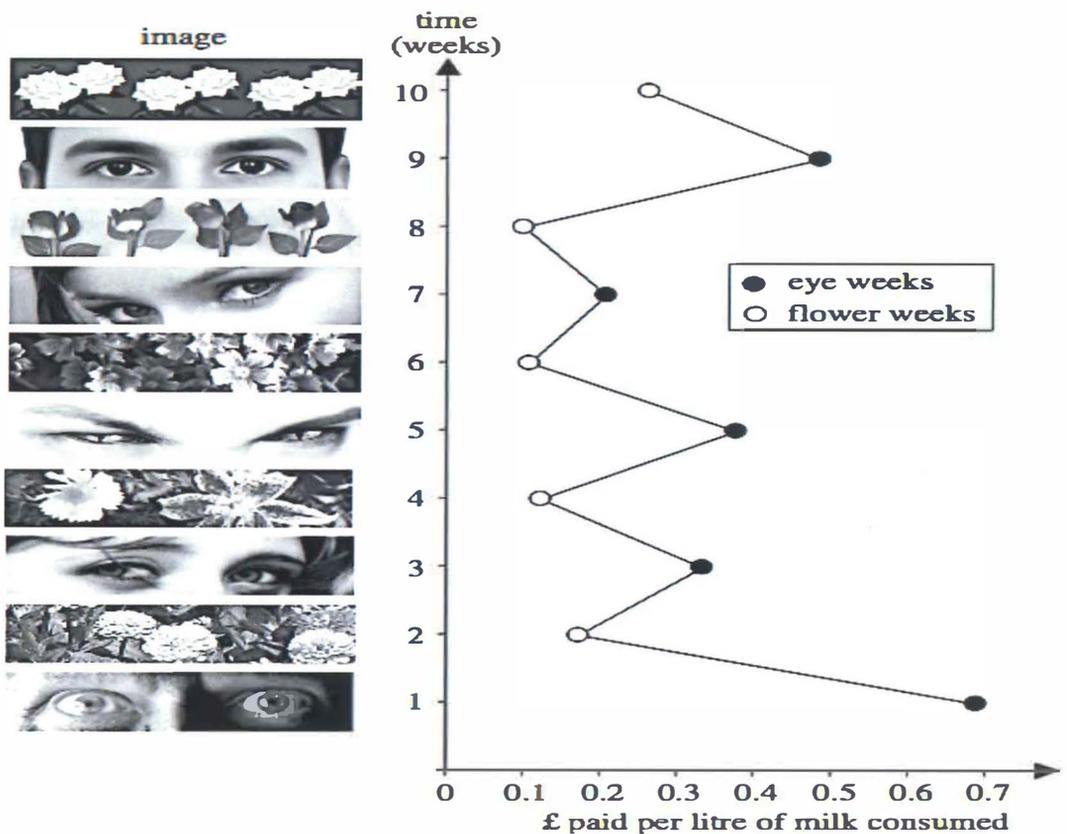


Figure 3.5: *Somebody is Watching*. When the posters are eyes, the eyes are symbols “somebody is watching”. The graph shows clearly that when the posters had eyes the payments were consistently greater. (Source: Bateson, Nettle & Roberts, 2006).

Slovic, Fischhoff & Lichtenstein’s experiment in 1988 showed that System I is dominant over System II. In an effort to change the emotional appraisal of their participants with regard to various technologies, they gave participants brief

statements some stressing the benefits of a particular technology others stressing the low risk of another. It was rather surprising to find that the participants who had read about the benefits of a given technology also changed their beliefs with regard to its risks although there was no evidence indicating so. As Kahneman (2011, p. 140) explains: “*the emotional tail wags the rational dog*”.

The same effect is seen in the social effects of prosopagnosia, a difficulty in recognizing familiar faces. People with this condition often cause unintentional offense, for example, by failing to greet friends and family who might happen to pass by on the street. Even when the friends and family know about their condition, they cannot help but feel offended. The fact that they are informed about the condition, nevertheless, does not seem to stop the emotional reaction (Yardley, McDermott, Pisarski, Duchaine & Nakayama 2008).

And finally, the two systems theory can draw ample support from the very well studied Stroop effect (Stroop, 1935). A widely used task, the Stroop effect is reliably produced each time when participants are presented, for example, with color words (i.e. Green, Blue) and asked to name as quickly as possible the color of the ink in which the words are printed. In a congruent condition the colour of the ink matches the word whereas in the incongruent condition the colour of the ink and the word mismatch. In the incongruent condition, participants frequently read the word itself even though the task requires them to speak out the ink colour. In the two systems theory, according to Kahneman (2011), System I overshoots its mark by doing more than the task actually demands which, in turn, involves the effortful processing of the System II to suppress the unrequired behaviour that would otherwise follow the System I activity. Stroop effect is a clear demonstration of the interplay between these two different modes of processing.

From an evolutionary perspective, System I enables an organism to make rapid decisions and is responsible for maintaining a fast and dynamic link with the reality of an environment which can change at any moment without notice. However, unless it is explicitly shown that the decisions it is making are wrong, System I will implicitly assume the opposite and continue without the need for much conscious thought (Kahneman, 2011). The neural bases of the interplay between these two systems, the evidence presented above seems to indicate, may reside in Frontal Lobes. The SAS model of the organization of the brain briefly described in Chapter 1 as well as Panksepp's model are largely congruent with the two systems explanation. All of these models share the opinion that the brain cognitive systems are largely separated between the automatic and voluntary systems and all agree that the automatic system is evolutionarily older, concerned with the heuristic, parallel processing, intuitive and fast and providing a psychoneural context for the operation of the voluntary system. On the other hand, the voluntary system is consistently described across these models as evolutionarily younger, concerned with finely grained cognitions and, in comparison generating subtler choices and having the capabilities for serial, analytic and abstract reasoning.

An important implication of the two systems theory is that, often, the aspects that affect the assessment of a situation and go on to have a profound influence on the decision making processes, which is the main reason why SA is studied, are often hidden from conscious awareness and, therefore, not directly accessible by questionnaire-type methods.

A particularly influential theory, which, it will be argued, can bring many important aspects of these theories together into a testable format has been proposed by Damasio (1994) and is known as the Somatic Marker Hypothesis. Initially based

on the peculiarities of the EVR case (see section 3.1.3 above), Damasio has attempted to weave together all the emerging puzzle pieces into a clearer understanding of frontal lobe functioning, their involvement in emotional processing and their role in regulating decision-making behaviour. A particularly useful aspect of the Somatic Marker Hypothesis is the idea that somatic states can learn to adapt to a situation and covertly influence decision-making. We can think of Somatic Markers functioning as part of an apparatus, which in a biological level is congruent with the State functioning and at a cognitive level with System I.

An explanation of Damasio's theory cannot be fully complete without considering its origin: the seminal work of two well known figures in psychology, William James and Carl Lange. We should note from the outset that Somatic Marker Hypothesis is at present just that, a hypothesis. Most researchers vary in the degree to which they endorse or reject the Somatic Marker Hypothesis, however, there is no doubt that it has generated, at times heated, debates. In this and the following two chapters, the Somatic Marker hypothesis features predominantly.

### 3.1.6 *Autonomic Nervous System and Emotions*

As mentioned above, the origins of Somatic Marker theory of emotions builds upon the work of William James and Carl Lange who around 1880s first came up with the theory later to be known as James-Lange theory of emotions (Friedman 2010; Lowe & Ziemke 2011). James (1890, p. 449) stated "*common sense says, we lose our fortune, are sorry and weep; we meet a bear, are frightened and run; we are insulted by a rival, are angry and strike ... this order of sequence is incorrect ... the more rational statement is that we feel sorry because we cry, angry because we strike, afraid because we tremble*". Similarly and independently from James, Carle Lange

(1885) emphasized the physiological mechanisms of the body, especially the vasomotor function, as important in supporting emotional states. The common aspect between James and Lange idea was that the bodily changes that follow perception of an exciting stimulus are, in effect, the emotion.

James pointed out that the emotions, such as fear, would be impossible without their correlate body manifestations: *“we feel sorry because we cry, angry because we strike, afraid because we tremble, and not that we cry, strike, or tremble, because we are sorry, angry, or fearful, as the case may be. Without the bodily states following on the perception, the latter would be purely cognitive in form, pale, colourless, destitute of emotional warmth.”* (James, 1884). Abstracting from emotion all the bodily symptoms, James argued, there is nothing left to account for the experience of emotions. Independently of James, Carl Lang also arrived at the same conclusion: *“If from one terrified the accompanying bodily symptoms are removed, the pulse permitted to beat quietly, the glance to become firm, the color natural, the movements rapid and secure, the speech strong, the thoughts clear, -- what is there left of his terror?”* (Lange, 1885).

Cannon (1929, p. 280-283) opposed the James-Lange theory of emotions arguing that the range and quality of emotions could not be adequately mirrored by body states. For example, qualitatively different emotions, such as fear and anger, are characterized by similar body states such as increased heart rate, inhibited digestion and increased sweating (see Bear, Connors & Paradiso, 2001, pg. 582 - 584). Cannon reported that transaction at the higher end of the spinal cord, which diminish feedback from the Autonomic Nervous System (ANS), did not lead to diminished emotions. Furthermore, Cannon (1929, p. 281) states: *“If these differences are due to other than visceral changes, why is it not always possible by voluntary innervations to produce*

*emotions? We can laugh and cry and tremble. But forced laughter does not bring happiness, nor forced sobbing sorrow, and the trembling from cold rouses neither anger nor fear”* concluding that emotions must reside exclusively in the brain (Cannon (1929, p. 280-283).

Evidence however, has not supported Cannon’s conclusions. Ekman and his colleagues carried out a series of experiments and demonstrated ANS specificity for different emotions (Ekman, Levenson & Friesen, 1983; Levenson, Carstensen, Friesen & Ekman, 1991; Ekman, 1992). Ekman instructed participants, muscle by muscle, to create on their face a specific expression of an emotion. He found greater activity of ANS following facial expressions of emotion. Furthermore, he found that the ANS and the heart rate increased when the expression mimicked a negative feeling (anger, disgust) relative to mimicked expressions of positive feelings. Other measures revealed that the finger temperature increased when the emotion simulated was anger as opposed to fear and moreover, when the reported feeling of emotion matched the facial expression, the ANS distinctions among the negative emotions were greater. Open-ended questionnaires were administered to measure participants’ subjective feeling of emotion, which established that the observed ANS activity following voluntary facial expressions was also followed by the appropriate subjective emotion. Ekman’s findings support the hypothesis that body states precede subjectively felt emotions and furthermore, that different emotions can be represented by emotion specific configurations of the body systems. These results were replicated cross culturally and across different age groups.

More recent studies have shown that spinal cord lesions very often do not completely disrupt the afferent signal from the peripheral to the central nervous system, which could explain, in accordance with James-Lange theory, the present

feeling of emotion on Spinal Cord Lesion (SCI) patients (Nicotra, Critchley, Mathias & Dolan 2006). Furthermore, Nicotra et al (2006) provided evidence that experience of emotions is hindered by such injuries, whereas Damasio (1999, pg. 60 - 61) points out that, even in an event of total disruption of communications between central and peripheral nervous systems via spinal cord, feedback is still transmitted via cranial nerves, facial muscles and facial viscera. Additional support for the James-Lange theory comes from the effects of benzodiazepines. Benzodiazepines (a particularly recognised branding of benzodiazepines is Valium) are often prescribed as muscle relaxants as well as anxiolytics. The assumption here is that it is hard to feel tense when all your muscles are relaxed.

An additional development that deserves mentioning was proposed by Schachter & Singer (1962). They affirmed the causal role that ANS plays in the generation of emotions, in accordance with James-Lange, but argued against ANS capability for emotion specificity. They argued that an emotion-non-specific physiological arousal is labeled at a later stage by the cognitive circumstances, which then turn the non-specific arousal into the feeling of a specific emotion. In a highly influential but heavily criticized study (Friedman, 2009), Schachter & Singer (1962) injected norepinephrine in two groups of people, one was informed about its effects the other was not. In the waiting room a confederate who posed as another participant, created either a euphoric or angry situations. As expected, they found that the group that did not know about the epinephrine and its effects behaved and reported feeling emotions consistent with the emotional environment created by the confederate. They did not find this in the group that new about the effects of the epinephrine injection. However, this theory does not explain the emotion specificity of ANS representations reported by other studies (i.e. Lacey, 1950; Ax, 1953), by Ekman (1983; 1992).

### 3.1.7 *The Somatic Marker Hypothesis*

Patric & James (2004) reported a case in a nuclear plant where operators evaluated as true a machine reading of a valve, which indicated that it was shut. The situation evolved in the following way: the reactor temperature rose tripping the reactor and electromagnetic valve. Sometime later a machine reading indicated that the valve was shut, when in fact it was open. Despite plenty of information indicating otherwise and which should have normally raised the alarm, the operators still believed for more than two hours that the valve was shut when in fact it was not. One of the psychological elements that contributed to this conclusion, Patrick and James suggest, was the fact that operators had prior knowledge about a persistent leak occurring on that valve, and it was this particular piece of knowledge that explained way all other conflicting information that was indicating otherwise. In terms of dual processes theory, an alternative explanation may be that System I processes could have concluded, erroneously, that the valve was displaying the same behaviour as before and overruled all other cues with which System II would have, according to the theory, otherwise been processing. Many people tend to rely on heuristics, such as the one that assigns a high level of credibility to machine readings, and rightly so because machines rarely fail; hence in both situations, operator's actions, or inactions, can be attributed to this type of heuristic reasoning which in this particular case led them to form an inaccurate representation of the situation. The question is, did they have any feeling at all during the sequence of events that something perhaps was not quite right? If yes, is it possible to detect such a feeling from changes in the brain or body physiology?

It will be proposed in this thesis that the Somatic Makers paradigm offers the best hope that such a measure can be developed and potentially used as an indicator of situation awareness processes within System I or State functioning. A particular advantage of the Somatic Marker theory with respect to the aim of this thesis is that Somatic Markers precede decisions. This means that the possibility of detecting the SM activity specific and prior to a disadvantageous decision hence an attempt to modify it prior to its enaction is conceivable. As will be discussed below, the Somatic Marker hypothesis makes predictions specific enough to be reliably tested. Though not absolutely precise, the neural architecture supporting the theory has been spelled out in some detail which makes it possible to target psychophysiological measures of Somatic Markers, especially EEG, with reasonable accuracy.

The first term of the label Somatic Markers, can be directly related to James-Lange theory of emotions. Damasio (1994, p. 174) states: "*Because the feeling is about the body, I gave the phenomenon the technical term somatic state ("soma" is Greek for body); and because it "marks" an image<sup>2</sup>, I called it a marker.*" The body, defined here in a general sense including visceral and non-visceral sensations, automatically marks the decision options with a negative or positive emotional signal based on the prior experience. This is a fast and automatic process, which quickly reduces the decision space with the effect of an increased efficiency of the conscious reasoning mechanisms. If we refer back to Chapter 1 and Chapter 2, the operation of the Information Bias (IB) also has a similar role of biasing information processing by restricting its information space. Furthermore, IB seems to be directly affected by the emotional aspects of information processing. There is therefore a clear parallel between the operation of Somatic Markers and Information Bias.

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<sup>2</sup> Images are defined as the main content of our thoughts not specific to any sensory modality but including all (see Damasio 1994, p. 106-108 for a detailed description)

According to Damasio, the valence of the SM markers is an expression of the learned behaviours and past experiences that are brought to bear in the assessment of any situation hence linking the consequences of each possible scenario that experience predicts to an emotional signal. A negative emotional signal will automatically inhibit or reject a large number of possible options whereas a positive one will bias the cognitions towards those options which prior experience has associated with positive outcome. The impaired functioning of the SM, therefore, impairs the speed and efficiency of System II processes by failing to reduce its range of choices to a size that System II can deal with; both the Gage and EVR cases demonstrate the widespread effects of the failure of this system. If the neural circuit that supports the functioning of SM is damaged, both the speed and the efficiency of making decisions is impaired to the point of near paralysis. As we have already seen, vmPFC functioning seems to have a central role in this.

Testing the hypothesis, Damasio et al., (1991) compared the performance of three groups in an emotional task (see below for details); group 1 consisted of five patients with bilateral lesions in lower medial frontal regions; group 2, which was the brain-damaged controls, included 6 patients with brain lesions elsewhere other than vmPFC and group 3 consisted of 5 normal non-brain damaged controls. All participants were exposed to three types of stimuli: 1) Elementary Unconditioned Orienting stimuli which has been shown to reliably induce Skin Conductance Response (SCR) in normal people (such as hand clapping close to the ear). 2) Target Pictures depicting emotionally charged images with “strong meaning” and 3) Non-Target Pictures with neutral images and no implied strong meaning and which did not usually elicit large SCRs. A further condition with two levels was introduced, Passive and Active; in the Passive condition, participants were not required to make any

verbal or motor response, whereas in the Active condition, participants were required to describe the content of the photos and the impact it made on them.

The findings showed that vmPFC patients did not generate discriminatory SCR in the passive condition but showed normal discriminatory SCR in the Active condition for target versus non-target. Normal SCR in vmPFC patients in response to Unconditioned Orienting stimuli (hand clapping) ruled out autonomic dysfunction. These results were replicated in a repeat of the experiment several months later and also two years later; vmPFC patients consistently showed no discriminatory SCR in the passive condition. This clearly points to a direct causal link between the damage to the vmPFC, the body's Autonomic Nervous System (ANS) and the well-documented cognitive impairments in decision making that follow damage to vmPFC.

In addition to studying patients with damaged vmPFC, support for SM hypothesis has been largely based on the Iowa Gambling Task (IGT). IGT will be described in greater detail further down but, to give an early overview, it has been widely praised for its ecological validity and subtle structure which have made it a widely used testing paradigm in many psychological experiments (see second paragraph below – section 3.1.7.1).

#### *3.1.7.1 Investigations of Somatic Marker Hypothesis using Iowa Gambling Task*

There are several variants of the Iowa Gambling Task (IGT) in use but the original version consists of five, 20 trial blocks where in each trial a participant makes choices from four concurrently presented decks of cards, A, B, C and D, for monetary gains. Typically, the two decks on the left, A and B, are set so that participants make higher gains (relative to decks C and D) but over time lead to a cumulative loss. Decks C and

Don the other hand offer lower gains but over time lead to a cumulative profit. Rewards are present in every trial whereas losses are intermittent.

IGT attempts to simulate real life decision-making conditions in laboratory settings and has shown differences in the decision making performance on vmPFC damaged patients as compared with the normal population (Bechara, Damasio, Damasio & Anderson, 1994). The IGT paradigm has also reliably shown expected discriminations in performance on a range of neurological and psychiatric conditions such as, addiction (Bechara & Damasio, 2002), schizophrenia (Whitney, Fastenau, Evans & Lysaker, 2003), obsessive-compulsive disorder (Cavedini, Riboldi, Keller, D'Annuncci & Bellodi, 2002), Huntington's and Parkinson's disease (Stout, Rodawalt & Siemers, 2001) drug abuse (Bechara, Dolan, Denburg, Hines, Anderson & Nathan, 2001) anorexia nervosa (Cavedini, Bassi, Ubbiali, Casolari, Giordani, Zorzi & Bellodi, 2004) patients with pathological gambling problems (Brand, Kalbe, Labudda, Fujiwara, Kessler & Markowitsch, 2005). It has also been used to show how people make economic decisions (Bechara & Damasio, 2005) and it has been enabled testing a dissociation between SM and Working Memory in neural and functional processes (Bechara, Damasio, Tranel & Anderson, 1998). Furthermore, dysfunction of SM in IGT has been found to correlate with hypersensitivity to reward and insensitivity to punishments as well as insensitivity to future consequences (Bechara, Tranel & Damasio, 2000).

The strengths of IGT, according to Bechara, Damasio, Tranel, & Damasio (1997a), rests on the fact that the reward/punishment schedules of the IGT are sufficiently obscure so that the learning that takes place is largely implicit. They also point out that the task offers a greater ecological validity when compared to other similar tasks such as the Wisconsin Card Sorting Test.

To assess the progression of implicit learning during the IGT task, Bechara et al., (1997) subjected vmPFC patients (n = 6) and healthy control group (n = 10), to a modified version of IGT which assessed participants' explicit knowledge of the task every ten trials beginning with the trial 20. The findings supported a categorisation of the development of knowledge from implicit to explicit into the following stages:

- I. pre-punishment – before major losses had been encountered (trial 1 - 20)
- II. pre-hunch – following the pre-punishment stage where participants were expected to start generating anticipatory SCR (trial 40 - 50).
- III. hunch – where most participants started to have some idea about advantageous and disadvantageous decks (trial 50 - 80).
- IV. Conceptual stage – where most participants were expected to have conscious knowledge of the rule underlying the game (80 +).

Most participants, Bechara and colleagues found, started to developed anticipatory SCR around the pre-hunch period, however, the most important finding in this study was that even though around 50% of vmPFC patients reached conceptual stage, in absence of anticipatory SCR (in other words, with an impaired SM system) they continued to make disadvantageous choices (Bechara et al 1997; Dunn, Dalgleish & Lawrence, 2006), which has led to the deduction that the SM biasing effects on the decision making are largely implicit and powerful. The conclusion that Bechara and colleagues came to was that vmPFC patients are unable to “*access complex signals reflecting records of previous experience shaped by reward, punishment, and the emotional state that attends them*” (Bechara et al., 1997, p.1294) which impairs their decision making behaviour.

A later study with IGT, also implicated the Amygdala in the neural circuit required for the generation of Somatic Markers. Bechara, Damasio, Damasio & Lee

(1999) found that patients with damage in the Amygdala displayed the same absence of SCR signal as did vmPFC patients. Additionally, participants with damage to Amygdala also did not show SCRs related to the post selection feedback. An important finding was that some normal controls whose performance on the task indicated that they did not learn the rules (they chose disadvantageously), also did not display discriminatory SCR prior to selection lending strong support to the idea that the optimal functioning of the SM is important in decision-making.

Other areas that are thought to play a role in the SM neural circuitry are the Insula, which facilitates bi-directional communication between affective inputs from limbic structures such as the orbitofrontal cortex, amygdala (McDonald, Shammah-Lagnado, Shi, & Davis, 1999) and anterior cingulate and the attentional prefrontal-parietal network in the processing of somatic states associated with risky decision making (Bechara, 2001; Paulus, Rogalsky, Simmons, Feinstein & Stein 2003) as well as the Somatosensory Cortex where it is which the body maps its internal states in the Central Nervous System (Bechara, Tranel, Damasio & Damasio, 1997b). Furthermore, Tranel, Bechara & Denburg (2002) reported that lesions on the right hemisphere were associated with the decreased performance in IGT more so than lesions on the left hemisphere which lends support the suggestion by Bechara & Damasio (2005) that right vmPFC may be associated with the negative SM whereas left with positive SM.

It should be mentioned that the use of IGT is not without controversy. For example. Steingroever, Wetzels, Horstmann., et al., (2013) highlight that the interpretation of the results on IGT is based on 3 key assumptions: (a) healthy participants learn to prefer the good options over the bad options; (b) healthy participants show homogeneous choice behavior; and (c) healthy participants first explore the different options and then exploit the most profitable ones. Re-analysing

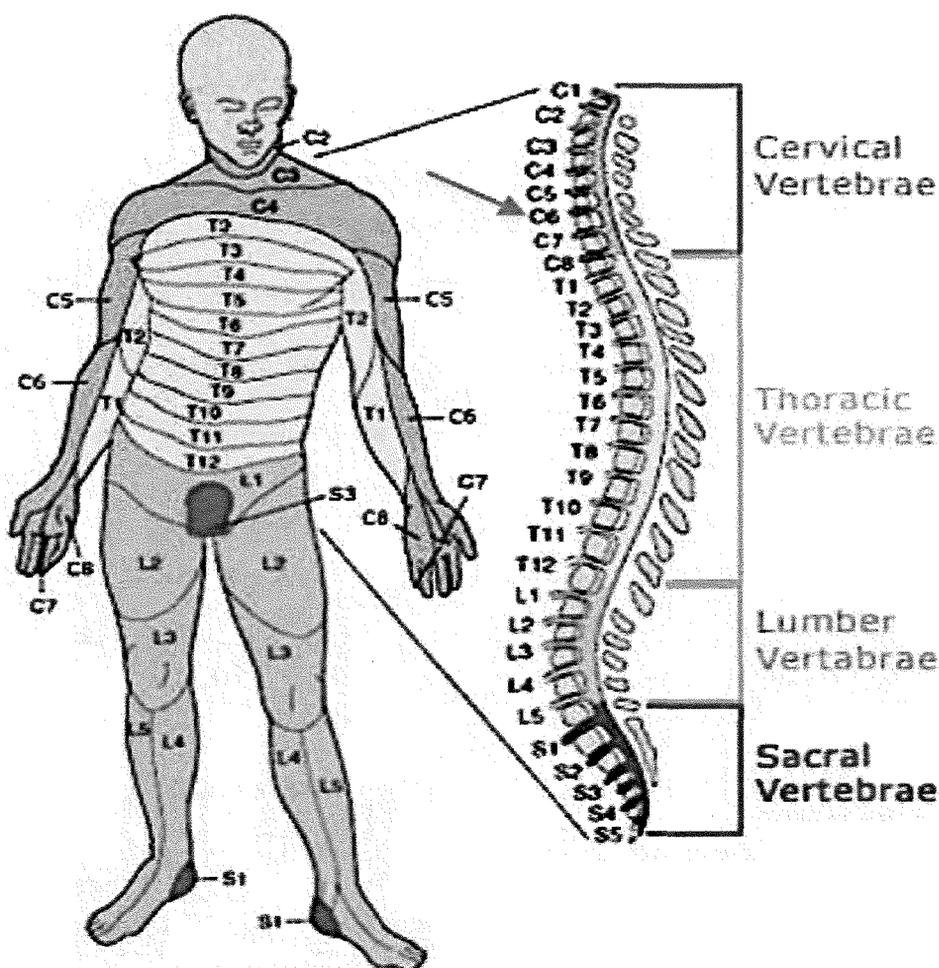
eight data sets in which IGT data came from healthy participants, they found that all the assumptions may be invalid; that is, (a) healthy participants often prefer decks with infrequent losses instead of the good decks; (b) healthy participants show idiosyncratic choice behavior; and (c) healthy participants do not show a systematic decrease in the number of switches across trials.

Also an effect has been found in chronic marijuana users who tend to perform poorly on the IGT. Wesleya, Hanlona, & Porrino (2011) contrasted 16 marijuana users against an equal number of controls; both performed a modified IGT in an MRI scanner. Marijuana user performed badly from beginning to end while there was no difference in group performance during the initial strategy development phase suggesting a decreased susceptibility of marijuana users to the negative emotional stimuli. While cannabis is associated with positive syndrome schizophrenia, it is unclear whether cannabinoids are also related to negative symptoms such as affective blunting. It is known that marijuana users are associated with schizotypy personality disorder (Skosnik, Park, Dobbs & Gardner, 2008) and attentional disinhibition (Skosnik, Spatz-Glen & Park, 2001), both of which could have an effect on how the participants perform in IGT.

### *3.1.7.2 The role of Automatic Nervous System (ANS) in Somatic Markers: The Communication Between ANS and Central Nervous System and its Effects on the Performance in Iowa Gambling Task*

Some studies using IGT with patients that have suffered various degrees of impairments on ANS and CNS communication via the spinal cord have not found that it leads to deterioration on the performance in IGT, which is what SM hypothesis predicts. In fact, a superior performance compared to controls on IGT has been

reported for patients with pure autonomic failure (Heims, Critchley, Dolan, Matthias et al., 2004). Furthermore, North & O'Carroll (2001) had also found no meaningful differences in the IGT performance between patients with spinal cord damage (full lesion at C6) and controls (see Figure 3.6). These arguments we have encountered before with the James Lange hypothesis and some of the evidence explaining this has been already discussed on section 3.1.6 above. However, there are two further aspects of SM hypothesis, which will be considered next, that help explain why and how patients with spinal cord lesions can perform well in IGT, in other words, suggest a functioning SM system despite the injuries.



*Figure 3.6: Organisation of the Spinal Cord.* Lesions at C6 do not lead to differences in IGT performance. Note that C6 location is high up the spinal cord. A complete lesion there disrupts almost (but not all) communication between ANS and the brain

### 3.1.7.3 *The “Body Loop” and As if Body Loop*

The body brain loop in the SM hypothesis has been extended to include an “as if Body Loop” (Figure 3.7). This system accounts for circumstances when a fast situation assessment is required that does not allow for the whole body loop system to come into play (Bechara & Damasio 2005). At this point, according to Bechara and Damasio, the “as if Body Loop”, the neural circuits of which reside entirely in the CNS, can simulate the appropriate body states from trained neural circuits in the somatosensory cortices without the need for the input from the body proper.

Bechara and Damasio suggest that both systems address different functional needs with the body loop being engaged in situations involving uncertainty whereas the “as if Body Loop” being engaged in the selection of risky choices. The evidence for this dissociation is limited and it is not clear why this is the case. For example, anticipatory SCR found in the Cambridge Gambling Task, which differs with IGT in the fact that its contingencies are explicit, hence avoiding ambiguity, are lower than on IGT.

Evolutionarily and Ontogenetically, the Body Loop precedes the “as if Body Loop”, Bechara and Damasio claim, with the as if Body Loop superseding the base mechanism and quite possibly being generally more active than it. The end result of either process, which can be either covert or overt to consciousness, is to represent the relevant facts related to a situation as somatosensory images (see Damasio 1994, p. 97-98 for a definition of images) and juxtapose them with stored image representations that include both the possible outcomes associated with a particular situation and the related emotional signals related to them. At covert level, the resulting emotional signal biases decisions away from what it marks as bad and

towards what it marks as good choices, whereas at overt mode it acts as an alarm or incentive signal respectively.

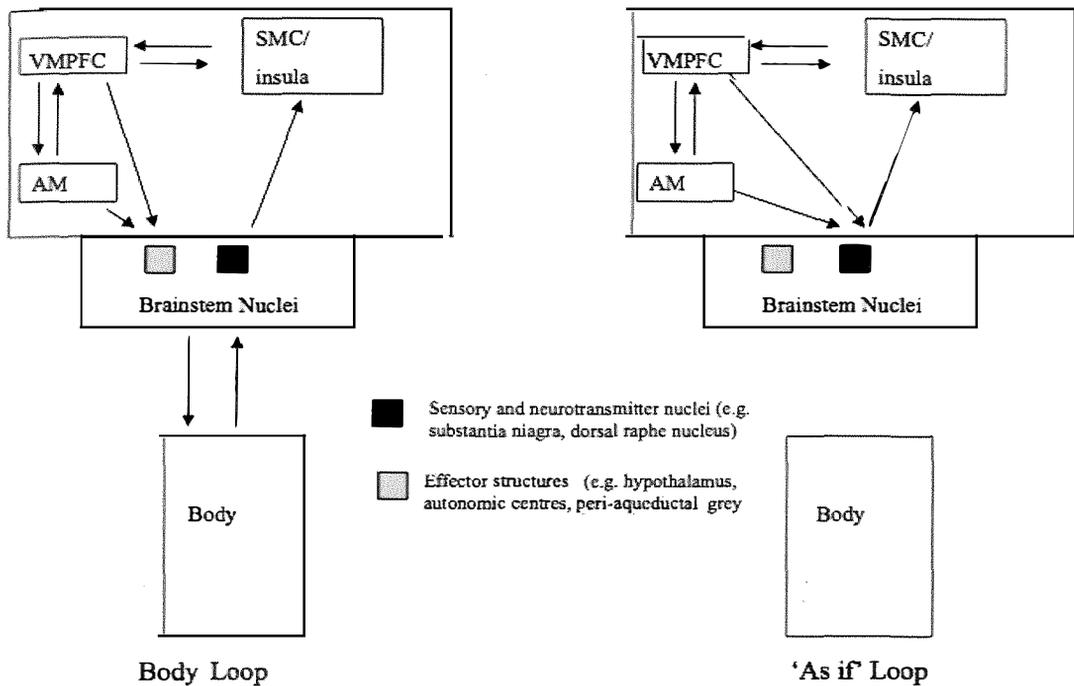


Figure 3.7: *The Body Loop*. Above are the neural structures that are proposed to support each of the systems, the Body Loop (left) and the as if Body Loop (source Dun et al., 2006)

Key: VMPFC, ventromedial prefrontal cortex; AM, amygdala; SMC, somatosensory cortex.

#### 3.1.7.4 Somatic Markers versus Reinforcement Learning in the Iowa Gambling Task

Many studies have implicated the role of OFC, a large part of which is vmPFC, in the stimulus-reinforcer associations (Fellows & Farah, 2003; Berlin, Rolls & Kischka, 2004; Deco & Rolls, 2005; Simmons & Richmond, 2008). In view of this evidence, Rolls (2004; 2005) has outlined an alternative model of the OFC functioning

implicating this region in the representation of reinforcers, monitoring changes in them and using that information to modulate previous stimulus-reinforcer associations to adapt with the current conditions. This would facilitate a rapid change in behaviour.

This role of the OFC in stimulus-reinforcer association learning, it has been argued, explains why some participants perform badly on IGT. For example, at the beginning stages of IGT procedure, the disadvantageous decks are initially advantageous, as they do not deliver a punishment until several selections later. By rearranging the punishment-reward schedule so that punishments occur on the initial deck selections, Fellows & Farah (2005) have found that the poor performance of the vmPFC patients was comparable to controls suggesting that reversing the previously established stimulus-reinforcer association learning (i.e reversal learning), not SM, was a more likely explanation why vmPFC patients perform poorly in IGT task. However, Bechara, and colleagues have pointed out that the location of the lesions of the vmPFC patients in this study was mainly in the right hemisphere, which is associated with working memory suggesting that the poor performance that Fellows and Farah found was more related to impairments in working memory not SM system (Bechara, Damasio, Tranel & Damasio 2005).

Furthermore, Turnbull, Evans, Bunce, Carzolio & Connor (2005), Turnbull, Evans, Kemish, Park & Bowman (2006) and Dymond, Cella, Cooper, & Turnbull (2010) have not found support that reversal learning does take place during the original IGT. However, they have developed a variant of the IGT, which they claim it does.

Turnbull, Evans, Kemish, Park & Bowman (2006) first proposed a novel variant of IGT which, in essence, extended from the original to include a second phase in which the reward/punishment contingencies were switched across so that

previously advantageous decks become disadvantageous and vice versa. The reward/punishment contingencies were systematically altered after the original IGT 100 trials in three signaled shift periods. Using this new paradigm, Tunrull et al., (2006) have shown that schizophrenic patients with negative symptoms (but not the one with positive symptoms) are impaired on the later trials of each shift period compared with controls. Patients with negative symptoms of schizophrenia suffer from a blunted affect (Carson 2000, p.638) which could explain, in accordance with the SM hypothesis, the impaired performance.

Dymond et al (2010) have further tested this new paradigm with a large number of normal participants (N = 206) in order to assess the role of the reversal-learning in IGT. Arguably, this modified version of IGT to include reversal learning has some advantages in context of the SA and compared with other SA measuring techniques. Most importantly, it provides a way whereby we can experimentally manipulate and measure learning, induce a change in situational circumstance which is in direct contradiction to the previous learning and observe how participants perform and how is this reflected in behavioral, and psychophysiological measures.

They introduced a few further adaptations from the original design; the task was computerized the subjective ratings of the goodness or badness of the deck were included and finally, the shifts in the contingency changes were not signaled. They found that at the onset of the contingency shifts, following the first 100 trials, the change did disrupt learning but the performance subsequently improved for each of the three contingency shifts. They also reported that low performers did overall select a higher proportion of previously-good-now-bad decks when compared to high performers.

### *3.1.8 Summary*

Considering the extremely complex systems and the numerous biological and psychological aspects involved in the generation of SM, It is not surprising that the SM hypothesis as well as its main experimental technique, the Iowa Gambling Task (IGT), have generated a considerable amount of controversy and debate over the years, (for an extensive critique see Maia & McClelland (2004), Dunn et al., (2006) and Colombetti (2008); but also see response, Bechara et al., (2005) with no general consensus emerging among researchers in this area yet. However, many agree that more studies are needed before a more nuanced understanding can be reached regarding SM (Colombetti, 2008; Dunn et al., 2006). The current investigation is aimed at furthering that understanding.

To summarise, theoretical and experimental evidence presented in this chapter, which encompasses different fields of research such as neuroscience and cognitive psychology, suggests the existence of two separate systems, each of which is underlined by different neural correlates, has different cognitive functions and the concerted product of which underlies many higher order cognitive functions not least decision making. With regard to decision-making, SM hypothesis suggests that embodied emotional factors associated with previous experiences are an important supporting factor and the malfunction of which greatly impairs the efficiency of its operations. In line with Panskepp (2004) description that channel functioning responds to pressures from global functioning (see above), and the dual processes theory which concludes from a cognitive perspective that System I greatly influences System II, the Somatic Marker hypothesis may fill an explanatory gap by spelling out in greater detail the mechanisms of interaction between the two in both psychological and biological perspectives. The underlying neural circuitry of the SM, more

specifically the pre frontal cortex, is a highly likely neural site to be involved in the integration of System I or Global functioning with System II or Channel functioning. If the operations of the SM system can be detected with methods that offer high temporal resolution, such as EEG, then there is, at least conceptually, a possibility of developing an on-line psychophysiological measure of the decision making system which can be incorporated in the existing measures of SA, especially the QASA model. QASA model of SA is particularly well suited since it is the only model that has explicitly developed a measure of SA based on the implicit cognitive construct of IB. It is not at all unreasonable to entertain the premise that IB and SM may be two sides of the same coin, first from the cognitive perspective and largely in line with operations of System I, and second from the neuroscience perspective. The functioning of the IB and the SM, as stated so far, are of aiding decision making by automatically simplifying the decision space.

In the next three chapters, a series of experiments will be presented whereby an attempt is made to develop an ERP measure of somatic markers and test it under various modifications of the IGT task, as first proposed by Tunrball et al., (2006). If an EEG measure of SM system is possible, then the behaviour of Somatic Markers can be investigated under systematically changing situational conditions, which, in theory, could lead to a valid biological marker that can be integrated with QASA measures of SA.

## Chapter 4 - Investigating Electroencephalography

### Correlates of Somatic Markers

#### 4.1 INTRODUCTION

As outlined in the previous chapter the primary evidence supporting the Somatic Marker Hypothesis has been based on studies utilizing the Iowa Gambling Task (IGT). Often described as an ecologically valid, interesting, easy to understand paradigm presenting a familiar environment to most participants, the IGT is also well suited to investigate aspects of implicit learning and, to a degree, its psychophysiological correlates. Regarding the latter, measures of Skin Conductance Response (SCR) have been central to the validity of the IGT and Somatic Marker (SM) hypothesis. However, the use of SCR has also meant that serious adjustments to the task have had to be made. Perhaps the most important adjustment has been the introduction of an intertrial interval of typically greater than 15s which is necessary to accommodate SCR recording restrictions (Dunn et al., 2006). This introduces a substantive confound in the ecological validity which is one of the main strengths of this task.

Other studies have used functional Magnetic Resonance Imaging (fMRI) (Fukui, Murai, Fukuyama, Hayashi & Hanakawa 2005; Li, Lu, Anaud & Bechara 2011) or electroencephalography (EEG) (Schutter & Van Honk 2005) all of which introduce their own brand of limitations on the ecological validity of the task. In comparison though, EEG is one method that can offer the least amount of interference on the original design as it is fast and relatively unobtrusive. On the whole, as Dunn and colleagues have also concluded, there are relatively few psychophysiological

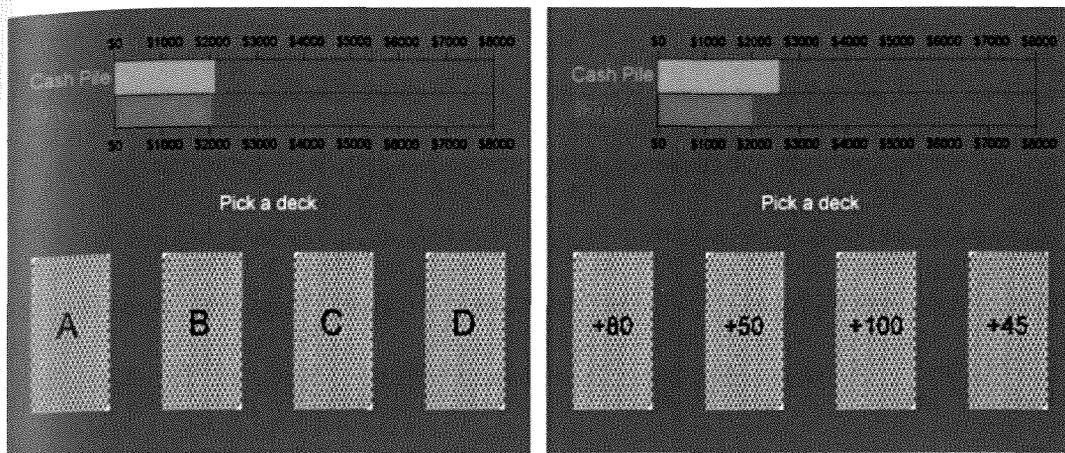
studies, which are done with IGT. Measures of SM markers, other than SCR, that confirm the previous findings would certainly offer strong support to the SM hypothesis. In this respect, the high temporal resolution of EEG and its potential to be integrated with the task with minimal adjustments make it a particularly preferred option.

There are relatively few studies that have used the IGT paradigm in EEG studies, none of which we could find has so far attempted to lock the SM signal with regard to a response in an Event Related Potential (ERP) type study. At first look, the SMs, as investigated by the IGT task, are ideal candidates for an ERP study since the SM signals once developed, according to SM hypothesis, are locked and precede each choice selection. However, even though it is thought that the SM signal precedes the conscious learning of the task, (see Maia & McClelland 2004 for an opposing argument), the duration from learning the task to reaching explicit insight, either side of which it would be futile to look for SM, at best is about 40 trials (Bechara et al., 1997). Within those 40 trials, there is no way to control how many would be related to disadvantageous choices and how many to advantageous ones. At best scenario, there would be 20 in each group which, even if this happened, it may not be enough for detecting SMs in an ERP; ideally, more trials are needed.

Increasing task difficulty and forcing the knowledge of the task to remain implicit for longer periods can overcome this methodological issue. This can be achieved in several ways. One way is reducing the margin between the gains and losses. However, this method would require many careful and systematic alterations of the margins to find the optimal point whereby participants learn the task but do not reach explicit knowledge, the so called “conceptual stage” (Bechara et al., 1997). An added difficulty is that there is no reason why the optimal point should be the same

for different people hence increasing the difficulty of taking this approach. One other way would be reducing the profit/loss margins between the decks while increasing the number of trials, however, a more elegant way may be increasing the amount of redundant feedback after each choice. This would create the conditions whereby there is more information than is needed to understand the situation which, in theory, would increase the cognitive effort and drive down performance.

If more than necessary feedback information was presented, redundant feedback, in the same modality, such as in the graphical or numerical feedback that is usually presented in the computerized versions of IGT, then each feedback source would be potentially competing for the same cognitive resources and drive performance down. As noted in the first chapter, more information does not mean better conditions for understanding; it can lead to the opposite. Most if not all of the online IGT tasks arrange the feedback so that there is no redundant information (see Figure 4.1 for a typical arrangement). This is just as well because the role of the feedback in the current IGT versions is to aid learning not make it harder. The following experiment will test the hypothesis that increasing the amount of feedback on the original IGT will make the task harder which means that the task may be adapted to extend the number of trials in which participants' behaviour is guided by implicit learning as opposed to conscious knowledge of the rules of the task. This can enable us to increase the number of trials through which we can look for the EEG correlates of Somatic Markers.



*Figure 4.1: A Typical Arrangement of the Decks in Iowa Gambling Task.* A typical computerised IGT does not have redundant feedback. (source Li, Lu, Zhong, Arnaud & Bechara 2010).

In the original version, participants are expected to reach the conceptual stage by around trial 80 (see previous chapter). With increased redundant feedback, it is hypothesized that the conceptual stage will be reached at later stages or not at all. Analysis of the behavioural data, the responses, can be used to assess whether the participants have learned the task at all. If in congruence with other studies the behavioural data indicates that there is a significantly increasing pattern of good selection choices, than that would support the argument that the task has been learned. In the normal version of the IGT, only around 70% of control participants reach conceptual stage, the remaining 30% who do not reach conceptual stage nevertheless perform normally on the task (Dunn et al., 2006). Increasing task difficulty may help reverse this ratio so that more participants do not reach the conceptual stage but nevertheless perform normally on the task.

Also, anticipatory SCR begins as early as the 20 to 40 blocks of trials (Bechara et al., 1997). Combining these factors together, a modified version of IGT with increased difficulty (redundant feedback) may allow us to look for an ERP of somatic markers in 80 trials, which would increase the power of their detection if

somatic markers were present and, more crucially, retain the original task structure without major alterations.

Furthermore, if the knowledge acquired during IGT is consciously realised toward the end of the task, as suggested by Bechara et al., (1997), then shifting the reward-punishment schedules across while maintaining the same learning rules will fail to show an interference; participants should be able to realise quickly that the shift has happened and modify their responses swiftly and accordingly. If, however, that knowledge remains implicit, than the reversal learning effect will increase difficulty of learning under the new and symmetrically reversed situational conditions. It is hypothesized that an ERP component related to SMs, if found in the original IGT version, will fail to emerge again in the reversal learning conditions.

The aim of this study is twofold, first to investigate whether knowledge which is IGT-related does ever become explicit with added redundant feedback and if not, whether the previously acquired SM signals may than cause interference to later learning, thus simulating conditions whereby the SM system is forced into a dysfunctional state that impairs rather than aids learning in healthy participants. Importantly, this could facilitate the exploration of the EEG correlates of the SM in its functional system states and, quite possibly dysfunctional system states. Dysfunctional in this respect means that the SM system essentially plays a disruptive function to learning.

In the following experiment, a modified and computerized version of IGT, involving two parts, will be administered. The first part will pertain to the original conditions of the IGT, namely, 100 trials and a similar reward/punishment schedule distributed across the decks, as reported in Bechara et al., (1996) with the addition of the redundant feedback. It is expected that in this procedure, in line with the other

studies, participants will start to develop SMs as the task progresses. The second part will replicate the first but the reward/punishment schedules will be reversed across the decks so that the previously 'safe' decks will become 'risky' and the 'risky' decks, 'safe'. The change in task conditions caused by the shift requires that participants adopt reversal learning – the SM that participants have developed in the previous task conditions will need to shift away from the already made associations and re-establish new ones to reflect the change; it is worth noting that vmPFC patients are also found to be impaired in reversal learning conditions (Dunn et al., 2006).

The main hypothesis that will be explored is that once SMs are established and linked to the task conditions in the first hundred trials, then that will create an interference effect on later learning that directly conflict SMs in the next hundred trials and impairs the ability of the participants to reorganise adaptively in the new task conditions. In other words, the previously established SM will become a hindrance to learning when the reward/punishment schedules are symmetrically reversed (i.e. the risky and safe decks swap over); hence, this is expected to demonstrate how SM system can sometimes lead to impaired performance in healthy people as well as suggest a mechanism by which sometime, prior experience or learning can be disruptive rather than helpful. As the task progresses and before reward/punishment schedules shift across, it is expected that EEG recording from the electrodes located on frontal areas of the scalp will start to show differentiation for risky versus safe choices prior to card selection. It is expected that this will not be the case in the reversal learning condition, the next 100 trials. The detection of the EEG SM signal and its relation to performance may offer an alternative, on-line, non-invasive measure to studying decision-making.

#### *4.1.1 Onset of Late Negative Slope of Bereitschaftspotential as a Possible Onset Latency of SM*

With regard to EEG correlates of the Somatic Markers, there is no prior research that explicitly has attempted to temporally lock the SM activity prior to each choice. The intertrial interval of 10s or more that is typical with SCR studies are less than ideal when it comes to translating it to an EEG type study since EEG's main strength is in its unparalleled temporal resolution in the order of milliseconds; 10 seconds in EEG is a relatively long time. So the question therefore is, where would be expected to find SM's biasing activity if, as predicted, it was preceding each choice?

After carefully considering the points of engagement of participants with IGT, it is clear that the actual physical enactment of a decision made in the IGT paradigm is a finger movement pressing a number associated with the selected choice on the keyboard. Literature on the movement related cortical potentials (MRCP), which are well known in EEG literature and are related to EEG potentials that occur around the time of movement onset, arguably, could indicate the best possible temporal location where we might be able to detect SM related activity; at the point when a decision is being acted upon we might expect the inhibiting or encouraging emotional signal to be strongest.

The earliest known MRCP component is the readiness potential also known as Bereitschaftspotential (Shibasaki & Hallett, 2006). Bereitschaftspotential, or Readiness Potential (henceforth referred to as BP) is a slowly rising negativity beginning 1 to 2 seconds before movement onset and is seen most strongly around the vertex area (Evidente & Caviness, 2009). BP is characterized by two main components, Early BP and Late BP. The Early BP beginning 1 to 2s before the movement onset and Late BP also known as Negative Slope (NS) is characterised by

a sudden increase in negativity at around 400ms, (Shibasaki & Hallett 2006). The Late BP is maximal around the contralateral central electrodes for hand movement, approximately electrodes C1 or C2 according to the international 10/20 system, and central for foot movement, approximately CZ.

While the early BP is most likely related with brain processes involved in movement preparation, such as the supplementary motor area, pre-supplementary motor area and lateral premotor cortex bilaterally (Evidente & Caviness, 2009), the Late BP is thought to reflect the activity of Primary Motor Cortex (M1) as neural systems underlying final movement execution are activated (Shibasaki & Hallett 2006). In studying the different EEG wavebands associated with BP, Pfurtscheller & Aranibar (1977), Pfurtscheller & Lopes de Silva (1999) and Pfurtscheller & Neuper (2003) have suggested that a power decrease in the alpha and beta bands prior to movement onset (Event Related Desynchronization) indicates an increase of the cortical activity in the corresponding area (Shibasaki & Hallett 2006).

Since the outward motor behaviour associated with the Iowa Gambling Task decision making option is a simple finger movement, selecting the response, the most likely time that the SM signal would activate is quite possibly during the onset of the Late BP, in other words, during the time that the M1 area is preparing the execution of the behaviour. It is at that point that we may be more confident that a choice has been selected and the appropriate biasing signal, SM, should be active at that point, inhibiting or encouraging the response. If this is the case, we should expect to find a greater activity of the related brain areas for the disadvantageous response selections (suppressed alpha) as compared to advantageous choices since, contrary to advantageous choices, the SM biasing signal is attempting to inhibit a behaviour that is already in process of being executed. If such a signal were discovered, than this

would support the Somatic Marker Hypothesis and open this theory to further investigations using EEG.

Therefore, it is expected that differences in the frontal area of the brain, more specifically, electrodes F3, FZ and F4, are most likely to show a differentiation between the advantageous and disadvantageous choices on the alpha band around the 400ms prior to response selection. According to the literature, the mid and left frontal areas are expected to underlie SM activity hence it is expected that electrodes FZ and F3 are more likely to show a differentiation between advantageous and disadvantageous response selections. BP is affected by laterality (Shibasaki & Hallett, 2006) therefore a right handed sample are likely to produce a greater effect on the left side of the cortex.

## 4.2. EXPERIMENT 2 – INVESTIGATING EEG CORRELATES OF SOMATIC MARKERS

### *4.2.1 Method*

#### *4.2.1.1 Participants*

Fifteen participants were randomly selected (opportunity sampling) mainly from students on the first and second year of the psychology course at the University of Gloucestershire (mean age = 32.44, SD = 14.94, 8 male, 13 right handed).

A subsample of this group, a total of 11, was asked to participate in a 128-channel EEG recording while completing the task (mean age = 34.00, SD = 15.59, 7 male, 2 left handed). All participants signed a consent form accepted by the Ministry of Defence Research Ethics Committee (see Appendix 4 for the form) prior to taking part in the study. Participants were not offered a monetary reward for participating in

the study and were made aware of their right to withdraw at any time without an explanation

#### *4.2.1.2 Materials*

##### Stimulus Presentation Computer

Stimulus presentation was controlled by e-prime version 2.0 (PST, Inc.), running on a Dell PC, using Microsoft Windows XP with Service Pack 2.

Each image was presented on a 0.48m diagonal, 4:3 aspect ratios and a computer screen with a frame refresh rate of 60 Hz. The screen was placed 1.5 m in front of the viewer, resulting in a picture presentation with a visual angle of 14.7 degrees of visual angle horizontally and 11 degrees vertically.

##### Apparatus

Each session involved the administration of a computerised version of the Iowa Gambling Task, provided by the experimenter, to assess decision-making. Further details of the experiment will be described below (section 4.2.1.3). Sessions took approximately 30-40 minutes.

##### EEG Recording

EEG data were recorded with Net Station 4.4.2, an EEG recording system (Electrical Geodesics, Inc. EGI, Eugene, OR), with a 128-channel Geodesic Sensor Net (Tucker, 1993). All electrode impedances were kept at 50 k $\Omega$  or below (Ferree, Luu, Russell, & Tucker, 2001). During signal collection, each electrode was referenced to the vertex. Data were sampled at a rate of 250 per second, and filtered offline with a 7-12 Hz bandpass filter. Prior research suggest that suppressions on this band, Alpha, may

indicate increased activity in the corresponding area (Pfurtscheller & Neuper 2003). EEG was recorded continuously using a Net Amps 300 (Electrical Geodesics Inc., Eugene, OR, USA). CZ (Vertex) was used as the reference. ElectroOculoGram (EOG) was monitored using electrodes placed above and below each eye. The electrode impedance was kept below 50 k $\Omega$  at the start of the recording. This range is acceptable given the high input impedance of the amplifiers of this system. Off-line analyses of the data were performed using Net Station 4.5.4 software (Electrical Geodesics, Inc., Eugene, OR, USA). The ERP data were sampled at a rate of 250 Hz. Trials were marked “bad” if the average amplitude exceeded 100  $\mu$ V, if they contained more than 10 bad channels, or contained eye movement in excess of 55  $\mu$ V. These automated criteria were supplemented by visual inspection. In the remaining trials, data for bad channels were replaced by a spherical spline interpolations algorithm implemented in Net Station using the data from remaining good channels.

#### *4.2.1.3 Design*

The study uses a within subjects design with two independent variables (IV): (1) Selection choices with two levels; each level representing advantageous and disadvantageous deck selections and (2) Electrode Position, which has 3 levels, electrodes F3, FZ and F4. The dependent variables (DV) was the EEG recordings from each electrode site (further details below).

The task had 200 trials overall. The first 100 trials were a replication of the original Iowa Gambling Task (IGT). On the second 100 trials, unbeknown to the participants, the patterns of rewards and losses were switched across the decks (see IGT task description below for more details) so that the previously created SM may be tested under the new, conflicting conditions. To assess the conscious knowledge of

participants, two questions were asked every ten trials, starting after the first 20 trials (see below for the exact questions asked).

#### *4.2.1.4 Procedure*

After giving informed consent, participants were led into a softly lit room and asked to sit in a reclining chair. Prior to starting the test, a verbal description of the experiment was given. The test itself was presented entirely on the computer screen and the experimenter was absent throughout the duration of the task. Participants were asked to follow instructions from the computer screen. While the experiment was running, the experimenter was located in an adjacent room. Upon finishing the task, participants were instructed to ring a bell to notify the experimenter.

#### Iowa Gambling Task (computerized version)

Following a few (6) pilot tests, the data from which is not included, the following modified version of IGT was developed. Pilot tests were mostly focused on the amount of feedback that would drive down performance enough to increase the number of trials that could be used to detect Somatic Markers. The arrangement shown in the figure 4.3 below was deemed to be the most optimal arrangement.

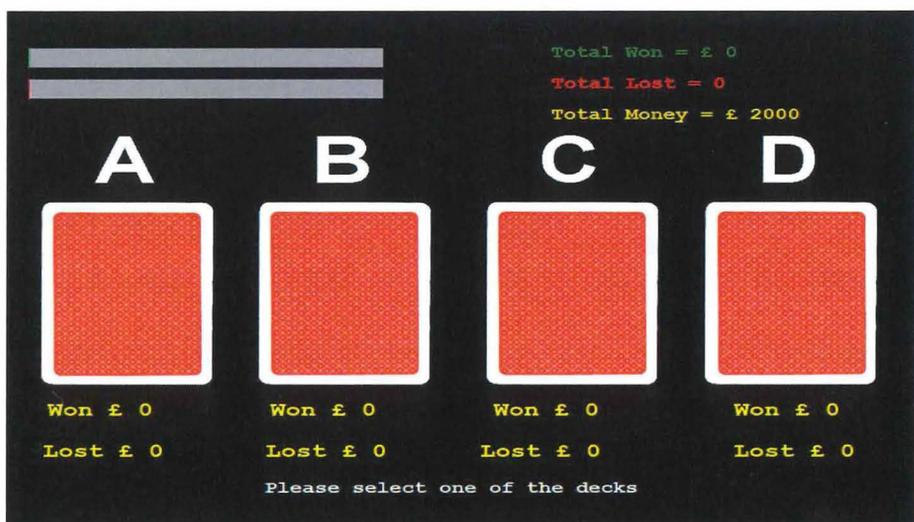
Similar to the standard administration of the IGT, participants were shown four decks of cards (A, B, C, and D) on a computer monitor (Figure 4.2) and started with £2,000 credit of fictional play money. Participants used a computer keyboard to select cards from the decks in 200 trials overall. The objective of the task was to make as much money in the long run as possible. Present on the screen and after each choice, there were a total of 13 sources of feedback. The feedbacks can be organised in two main groups of feedback mechanisms, the Long-Term feedback which would

be the Graphs and the running Total tally of Wins and Losses and the Immediate feedback which is feedback from each card selection.

The Graph section has two levels, green representing accumulated gains, red representing accumulated losses; the longer the green bar the more the participant had won and the longer the red bar the more the participant had lost. The Total tally group has three further levels showing an ongoing tally of losses, a 'Total Won' in green colour, 'Total Lost' in red colour and 'Total Money' in yellow colour.

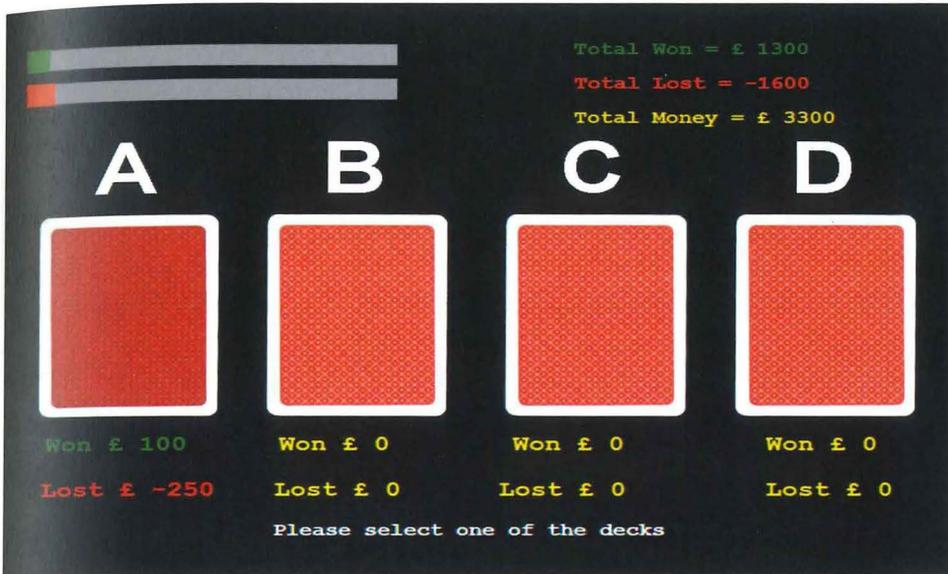
The Immediate feedback has two levels across four decks. At rest the participants sees two yellow lines of text labeled Won and Lost underneath each deck. When a choice is made, the winnings are shown as green and the losses as red. The amounts stay on screen for 500 ms while at the same time the other feedback groups are updated accordingly.

The subject did not know either the reward/punishment contingencies of the cards or the total number of trials. The rewards and punishments were immediately displayed at the time the participant selects a deck (Figure 4.2 and 4.3).



*Figure 4.2: Arrangement of Card in the Modified IGT Task.* The screen participants saw at the beginning of the experiment. There were three running sums on the top right, continuously updated that gave the participants information about losses, winnings and the sum total. The two bars on the top left provided a visual

representation of wins and losses, with wins represented with colour green on the top bar, and losses represented with red on the bottom bar. Underneath each deck there were two running counts, which provided information about winnings and losses associated with each individual card selection.



*Figure 4.3: Feedback After Each Response in IGT Task.* After each selection (in this case Deck A), the sums were immediately updated. There was also visual feedback indicating the choice made (the selected deck changed colour). The visual feedback stayed on screen for exactly one (1) second. This also defined the minimum of intertrial interval.

Two of the decks (the “safe” decks: C and D) featured relatively low monetary gains and occasional low losses with a net gain of £250 over ten trials; the other two decks (the “risky” decks: A and B) feature larger monetary gains with occasional large losses and a net loss £250 over ten trials. The mean initial reward per trial was £107.30 for deck A, £116.90 for deck B, £54.90 for deck C, and £52.50 for deck D; and the mean subsequent monetary loss is £149.50 for deck A, £163.30 for deck B, £26.30 for deck C, and £21.20 for deck D. The total time taken by the participant to complete the task was approximately 45 min.

Unbeknownst to the participants, after the initial 100 trials the patterns of winnings and losses assigned to each of the decks was reversed so that rewards and

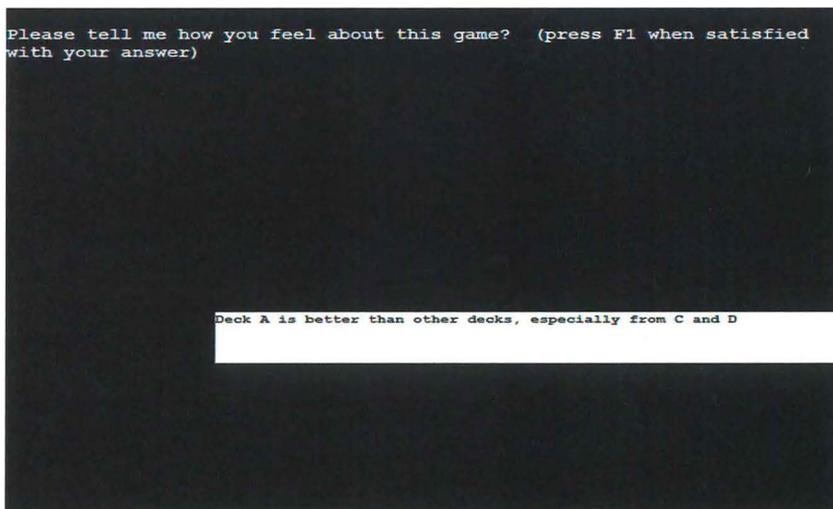
punishments initially associated with Deck A were assigned to Deck C, those of Deck B to Deck D and vice versa so that the frequencies of rewards and punishments were kept the same and only the long term gains swapped.

Initially, after the first 20 trials and afterwards every ten trials up to a hundred (100), participants were asked to answer two questions (Figure 4.4):

1. Please tell me how you feel about this game?
2. Please tell all you know about what is going on in this game?

The same pattern of questioning was replicated after the 100<sup>th</sup> trial, on the second phase of the task.

While participating in the task, eleven of the participants' brain waves were recorded using a 128 channel, HydroCel Geodesic Sensor net, part of the EGI, EEG system as described above (4.2.1.2).



*Figure 4.4: The Questions Screen.* Two questions will be presented on-screen. Participants answered using the keyboard.

Upon termination, participants were given a full verbal and written debriefing.

### 4.2.2 Results

This section will be divided into two further subsections: Analysis of Behavioural Data and Analysis of EEG data.

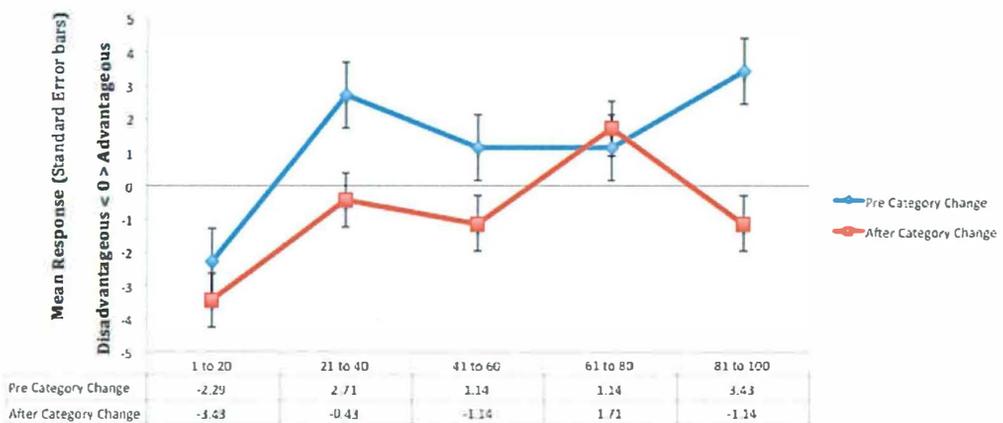
#### 4.2.2.1 Behavioural Analysis

Performance score on the IGT was split into five equal blocks of twenty card selections for the first hundred trials (Phase 1) and the same for the second hundred trials (Phase 2). For each block, a net score was calculated based on the number of card selections from the advantageous decks (C + D in the first part of the experiment) minus the number of card selections from the disadvantageous decks (A + B), so that the Calculated Score =  $(C + D) - (A + B)$ . Thus, a positive score reflects a higher ratio of selection from the advantageous decks and a negative score a higher ratio of selection from the disadvantageous decks. A zero score means that selections were equal on both, advantageous and disadvantageous decks. This is reversed on the second part of the experiment, after category change (Phase 2) since the advantageous decks become disadvantageous and vice versa. Table 4.1 shows the mean and standard deviation for each Block Selection for before and after category change (Phase 1 and 2 respectively). The table shows that there was a steady increase in learning for all participants over the five blocks for both Phase 1 and Phase 2. There are, however, an overall larger number of advantageous responses for Phase 1. The biggest increase for both phases seems to be from block 1 to block 2 but overall the response lines seem to roughly approximate the same shape although the overall scores are more negative for post category change (Graph 4.1).

Means and Standard Deviations of the First and Second 100 Trials (N = 15)				
Trials	Before Category Change		After Category Change	
	Mean	SD	Mean	SD
1 - 20	-2.53	4.98	-2.93	5.18
21 - 40	2.67	5.00	-0.93	5.55
41 - 60	1.20	3.91	-1.73	6.41
61 - 80	0.80	5.00	1.07	6.63
81 - 100	2.40	8.25	-0.67	3.83

Table 4.1: Means and Standard Deviations for the Behavioural Data (Normalised Outliers). Means and Standard Deviations for the first and second 100 trials, grouped in sets of 20 trials. The distribution of means show an increasing trend toward advantageous choices in the first 100 trials, but not so in the second 100 trials.

After the category change (phase 2), participants' responses shift back towards disadvantageous choices and in contrast to the pre-change phase of the experiment, a higher proportion of participant choices were made from disadvantageous blocks all the way to the end of the task, apart from Selection Block 4 (Graph 4.1).



Graph 4.1: Means of Pre and After Category Change with SE Bars. Responses below zero mean that the proportions of choices from disadvantageous decks (risky) are higher than those from advantageous decks (safe). Before changing the reward/punishment schedules, the first 100 trials, participants' responses show a clear trend, favouring advantageous decks more in each successive block and overall, apart from block 1, showing a higher ratio of selection from advantageous decks. After reward/punishment reversal, this trend disappears; participant's responses consistently

favour selections from disadvantageous decks, though there still appears a trend to shift toward more safe choices as the task progresses.

Responses were subjected to a repeated measures two-way analysis of variance (ANOVA) with five levels of trials Selection Blocks (each block was the mean of the 20 trials in a successive fashion starting from the first Selection Block 1 to 20) and two levels of before and after the category change, Phase 1 and 2.

Using Boxplots, outliers were detected in Selection Blocks 1, 3 and 4 for before Category Change and 1, 2, 3, 4 and 5 for after Category Change. The outliers were replaced with the value closest to the outlier. Also, the assumption of the normal distribution of Selection Block 3 Phase 1 was violated as assessed by Shapiro-Wilk test ( $p < .05$ ) hence Greenhouse-Geisser correction was applied to the analysis; all the other levels were normally distributed. The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > .05$ ).

There was no statistically significant interaction. There was a main effect of Selection Blocks which showed that there was a statistically significant difference in the selection of cards from Advantageous to Disadvantageous decks between different time points encompassing both categories  $F(2.89, 40.50) = 2.96, p < .05, \eta^2 = 0.18$ . Repeated contrasts revealed that there was a significant increase in selection of safe decks on Selection Block 2 as compared to Selection Block 1,  $F(1, 14) = 8.96, p < 0.02, \text{partial } \eta^2 = 0.39^3$  but no significant differences between comparisons of other successive blocks. This suggests that participants learn to respond adaptively from the second block of trials onwards.

<sup>3</sup> Partial ETA Squared: ranges from 0 to 1, 1 indicating a large effect size (see Richardson, 2010 for a full review)

### Subjective data

The answers to the two questions were examined to detect whether participants explicitly discriminated between Disadvantageous and Advantageous decks (see Appendix for the data). The text was searched for explicit statements which said that either decks A and B were bad or Disadvantageous or C and D were good, Advantageous or any other similar meaning word, and vice versa after the reward/punishment schedules were reversed across decks.

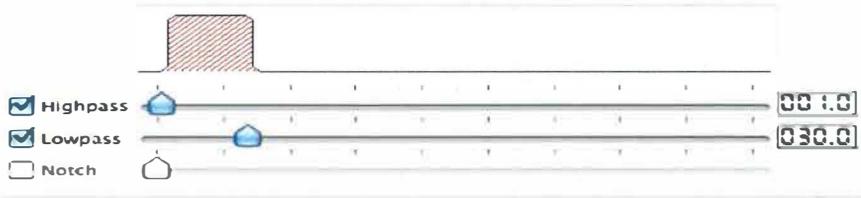
As expected, the evaluation of participants' answers to the two questions revealed that the participants did not reach the conceptual stage in either phase of the modified IGT task. In the initial stages most participants indicated that the selections were random in terms of wins or losses. As the task progressed, around trial 60, participants expressed either boredom, frustration but also some remained positive about the task, one describing it as compelling. Towards the end of the task many participants indicated randomness, frustration and boredom. Some of the participants did remain engaged all the way although their answers did not indicate they had a better understanding of the underlying rules of the task.

#### *-4.2.2.2 EEG Data Processing*

The EEG data was acquired with Net Station 4.4.2 and processed with Net Station 4.5.4. The processing of the data was done in two stages called pre-processing and post-processing. After pre-processing stage, the data were manually inspected for artefacts and marked accordingly. Below, the data processing stages are outlined in detail.

*Step 1: Pre-processing* - Filtering, Segmenting and Artefact Detection (Figure 4.5).

## Filter Settings:



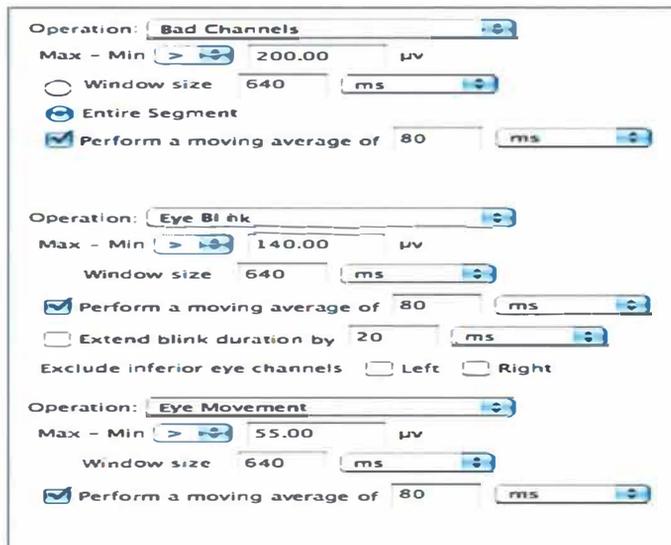
1

## Segmentation Settings:



2

## Artifact Detection Settings:



3

Figure 4.5: EEG Tools, Pre Processing. The data was first filtered from 7 to 12z (Alpha) – see 1 above. After which, the data were segmented (see 2) from 450 to 250ms before each response for Advantageous and Disadvantageous choices and for before and after Category Change. This way the segmentation encapsulates fully the 400 to 300 milliseconds either side of the onset of the Bereitschaftspotential. Automated Artifact Detection was run next (see 3) with the shown settings.

Since the behavioural data suggests that Somatic Markers were likely generated right after the first Selection blocks for both phases and the conceptual stage was not reached, the first block of trial from each phase was dropped and the

segmentation included all of the remaining 80 trials. This produced two IV with two levels each, Response Selection Disadvantageous and Advantageous (named in the segmentation tool as Negative and Positive respectively – G1 stands for Phase 1 and G2 for Phase 2) and Category Change, Phase 1 (before category change) and Phase 2 (after category change). A minimum threshold of 20 trials in each Response Selection level for each level of Category Change was applied. All participants satisfied this condition. The data were then subjected to the Artefact Detection (see Figure 4.5) tool to analyse for Bad Channels, Eye Blinks and Eye movements. According to the EGI engineers, the above settings are successful in detecting the artefacts for about 96% of the adult population and the artefact detection algorithms are based on the work of Gratton, Coles & Donchin (1983) and Miller, Gratton & Yee (1988). In addition, the data were also manually inspected for artefacts. If the data was perceived to have eye blinks, eye movement or other artifacts, the segments were marked as bad and excluded from further analysis.

*Step 2: Post Processing - Bad Channel Replacement, Averaging and Re-Referencing (4.6).*

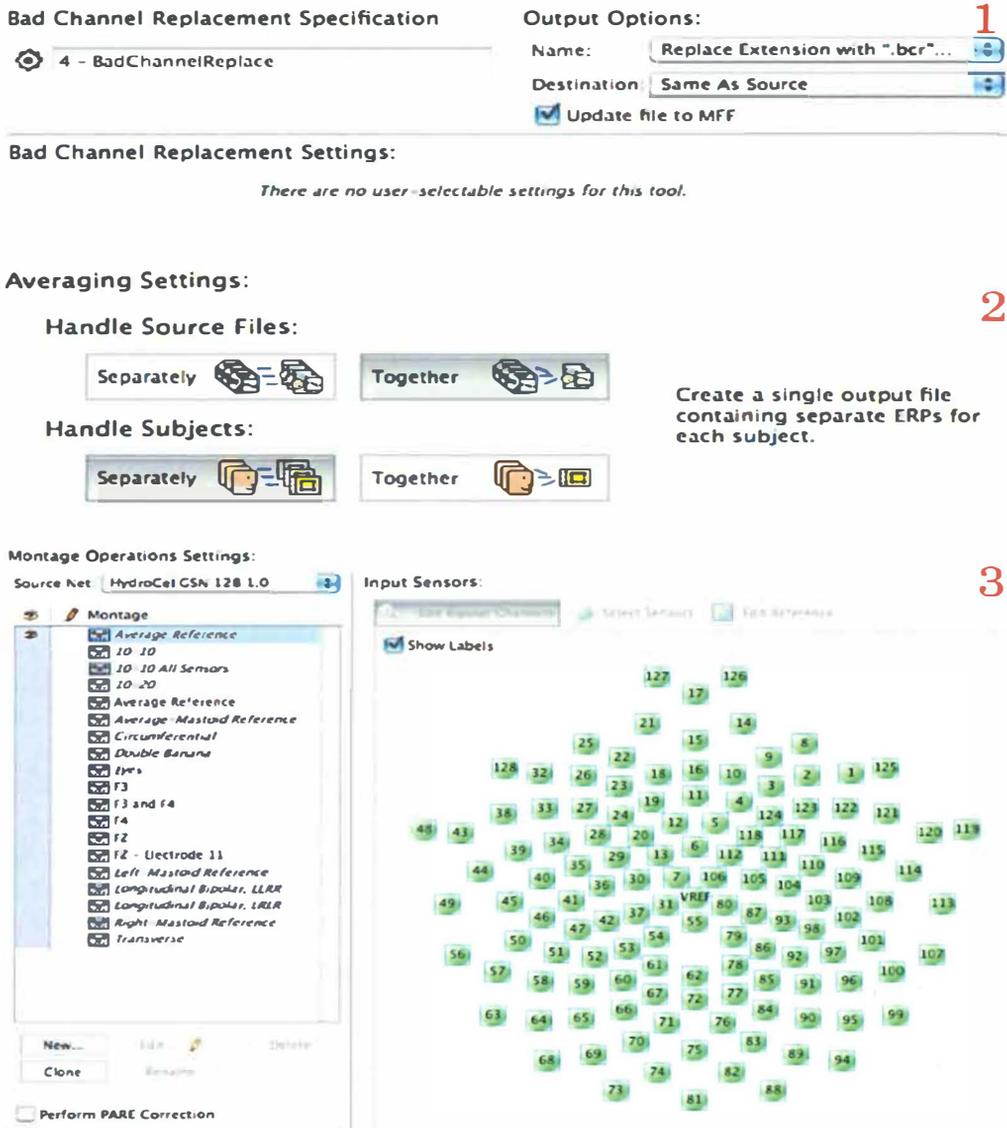
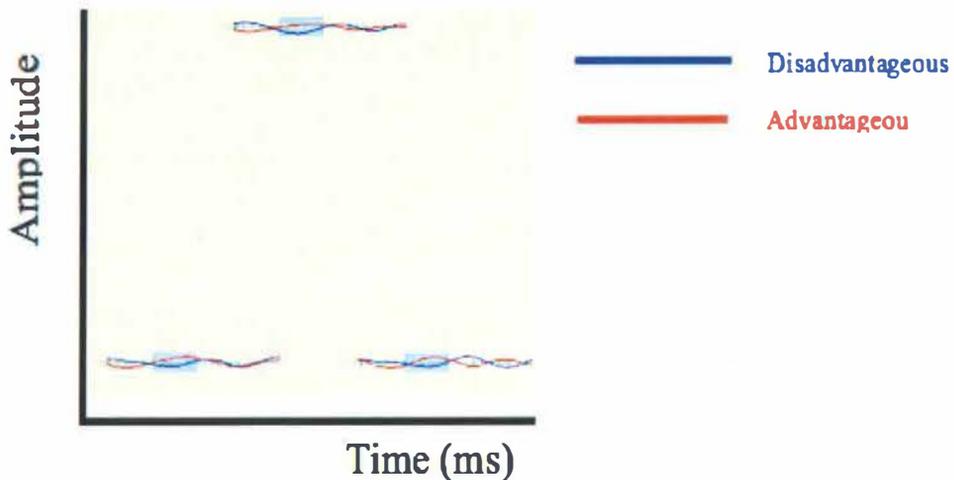


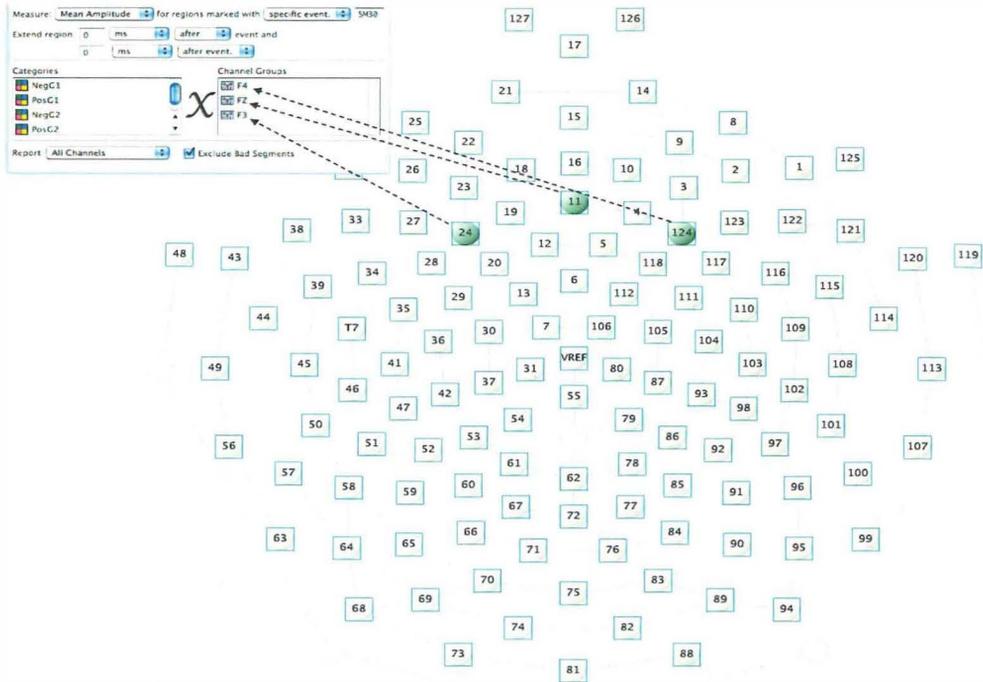
Figure 4.6: EEG Tools, Post Processing. The bad channel replacement (see 1) algorithm replaces every sample of every channel that is bad for that segment with data interpolated from the remaining channels using spherical splines interpolation algorithms. The resulting waveform is an approximation of the signal that was present at that location on the scalp during recording. The average tool (see 2) averages all the segments in each group to a single, average segment from all the segments that were not rejected, for each of the categories created during segmentation. The tool outputs a single file containing separate ERPs for each subject. To eliminate the influence of the arbitrary recording reference channel the data are re-referenced (see 3) to the average reference.

### Data exploration and extraction

During the exploratory stage of EEG data, the Grand Averaged data were inspected to determine the area where the SM marker could be visually detected, if present, on F3, FZ and F4 which are traditionally the frontal electrodes within the 10/20 international system. The time period between the 450 to 250ms prior to stimulus presentation was examined. On all three channels, the area between 400ms to 300ms seemed to show the largest increase of Alpha power (increase in power mean low activity on the corresponding area, decrease, more activity – see section 4.1.1 above) for advantageous response selection as compared to disadvantageous response selections. That region was marked for the three locations and the mean voltage value was extracted for further analysis (also see figure 4.7).



*Figure 4.7: Selecting the EEG Temporal Region of Interest – Grand Averaged Data are shown Above. The mean amplitude was marked from 400 to 300ms prior to response as a possible time frame for SM generation for electrodes F3, FZ and F4 (the blue shaded area).*



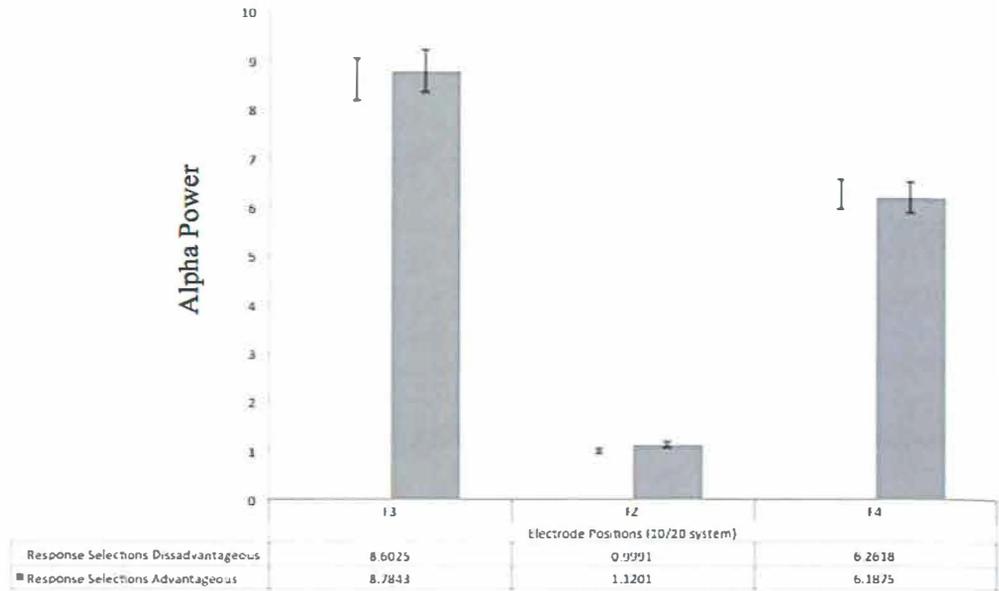
*Figure 4.8: EEG Data Extraction.* The mean voltage value (in microvolts) for each participant was calculated from the time window of 400 to 300 ms before the response for each of the three locations, F3 (electrode 24), FZ (electrode 11) and F4 (electrode 124). Then the mean amplitude data was extracted using Statistics Extraction Tool for the four groups representing: NegG1 = ERP data for 400 to 300 ms before each Disadvantageous choice was made for pre-Category Change condition; Neg2 = the same for after-Category Change condition; PosG1 = The same for the Advantageous choices for pre-Category Change condition and PosG2 for after-Category Change condition.

The mean Amplitude was extracted for 400 to 300 ms prior to the choice being made for three locations of electrodes, F3, FZ and F4 according to the international 20/20 system (Figure 4.8).

#### *4.2.2.2.1 EEG Analysis for the First 100 Trials – Exploring Somatic Markers' EEG Correlates*

A 3X2 repeated measures ANOVA (3 electrode positions and 2 choice selections respectively) was conducted to determine whether there were statistically significant

differences in EEG alpha mean voltage amplitude for 400 to 300ms prior to response for F3, FZ and F4 electrodes for advantageous and disadvantageous response choices. Inspection of the data revealed no outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ( $p < 0.05$ ), respectively. The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). There was a significant interaction between Electrode positions and Advantageous and Disadvantageous response selection  $F(2, 20) = 5.26, p < 0.02$ , partial  $\eta^2 = .34$ . The alpha amplitude across three electrode positions (measured in microvolts -  $\mu\text{V}$ ) was statistically significantly different for advantageous and disadvantageous response selections, with alpha amplitude decreasing for disadvantageous choices for electrodes FZ and F3 ( $M = 1.00, SD = 4.92$  and  $M = 8.60, SD = 5.59$  respectively) when compared with advantageous choices ( $M = 1.12, SD = 4.89$  and  $M = 8.78, SD = 5.67$  respectively). For electrode F4, the alpha amplitude for disadvantageous response selections increased ( $M = 6.26, SD = 6.00$ ) when compared to advantageous responses ( $M = 6.19, SD = 6.10$ ), (see Graph 4.9). We can therefore conclude that alpha power and consequently the underlying brain activity was significantly differently represented in left, middle and right frontal areas for advantageous and disadvantageous selection choices.



*Figure 4.9: Alpha Power For Disadvantageous and Advantageous Responses (mean alpha power in  $\mu\text{V}$  (CI 95 %)): The lowest alpha power is found on the FZ electrode. Both, FZ and F3 show an overall decrease of alpha power for disadvantageous choices when compared to advantageous ones. F4 shows a reverse trend.*

*Post-Hoc Analysis:* To further investigate the interaction, simple main effects were explored by running two separate, one way repeated measures ANOVAs for two levels of Response Selections. Since the conditions for running parametric tests, paired samples t-tests, were not met three Wilcoxon Signed-Rank tests for each electrode position comparing disadvantageous and advantageous response selections were undertaken.

#### One-way ANOVA - Alpha Power for Disadvantageous Responses

A repeated measures ANOVA determined that mean alpha amplitude differed statistically significantly between different electrode positions for Disadvantageous response selections ( $F(2, 20) = 6.56, p < 0.01, \eta^2 = .40$ ). Post hoc tests using the Bonferroni correction revealed that alpha power for FZ electrode was smaller than for

F3 ( $1.00 \pm 4.92$  vs.  $8.60 \pm 5.59$ , respectively), which was statistically significant ( $p < 0.02$ ).

#### One-way ANOVA - Alpha Power for Advantageous Responses

A repeated measures ANOVA determined that mean alpha amplitude differed statistically significantly between different electrode positions for advantageous response selections  $F(2, 20) = 6.48, p < 0.01, \eta^2 = .39$ . Post hoc tests using the Bonferroni correction revealed that alpha power for FZ electrode was smaller than for F3 ( $1.12 \pm 4.89$  vs.  $8.78 \pm 5.67$ , respectively), which was statistically significant ( $p < 0.02$ ).

#### Wilcoxon Signed-Rank – Alpha Power for Responses for each Electrode Position

Three Wilcoxon Signed-Rank tests were run to determine if there were differences in the mean alpha power for each electrode position separately, F3, FZ and F4, for advantageous and disadvantageous response selections. There was a decrease in alpha power for FZ electrode for disadvantageous response selection ( $Mdn = 1.17$ ) which was just on statistical significance  $z = 1.96, p = .05$ . 9 of the 11 participants showed a decrease whereas two show an increase in alpha power for disadvantageous selection response as compared to advantageous selection responses.

No significant differences were found in the other electrodes examined for advantageous and disadvantageous response selections.

#### 4.2.2.2.2 EEG Analysis for the Second 100 Trials – Exploring Somatic Markers' EEG Correlates

As for the first 100 trials, a 3X2 repeated measures ANOVA (3 electrode positions and 2 choice selections respectively) was conducted for the second 100 trials to determine whether there were statistically significant differences in EEG alpha mean voltage amplitude for 400 to 300ms prior to response for F3, FZ and F4 electrodes for advantageous and disadvantageous response choices. Inspection the data revealed no outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ( $p < .05$ ), respectively. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ) so Greenhouse-Geisser corrected results were considered. There was no statistically significant interaction  $F(1.12, 11.22) = 1.89, p > 0.05$ . The alpha amplitude across three electrode positions was not statistically significantly different for advantageous and disadvantageous response selections,

The main effect of Electrode Position showed a statistically significant difference in mean alpha power for three electrodes,  $F(2, 20) = 9.62, p < 0.01$ , partial  $\eta^2 = .49$ . Post hoc tests using the Bonferroni correction revealed that recorded mean alpha power was significantly reduced for the FZ as compared to the electrode F3 ( $0.24 \pm 1.45$  vs.  $9.31 \pm 1.95$  respectively) that was statistically significant ( $p < 0.01$ ).

### 4.3 DISCUSSION

The operations of SM were investigated in two conditions in a modified version of the IGT. The first condition, similar to the original IGT task (Bechara et al., 1996), consisted of 100 trials in which participants were required to choose between four

decks. The reward/punishment schedule was arranged so that the decks A and B were the disadvantageous or risky decks yielding an overall loss of £250 for every ten selections, whereas the advantageous or safe decks C and D yielded an overall win of £250. The second condition reversed the reward/punishment schedule so that the decks A and B yielded an overall win of £250 and decks C and D yielded an overall loss of £250.

The behavioral results of the modified IGT task revealed that in the first twenty trials participants' selection choices were biased toward the 'risky' decks A and B for both phases, pre and after change. As the game progressed however, participants' responses were progressively biased toward the 'safe' decks, C and D, reaching the peak at the last block – Block 5 for the pre category change condition alone. The task shows a general improvement between block one and block two which indicates that learning did take place.

After the category change, the mean scores for each block show a general trend of a higher ratio of selection for disadvantageous decks. There was no clear observable trend of increasing selection ratio of advantageous decks. There is a clear increase of the ratio of selection from advantageous decks from Block 1 to Block 2 but after that, apart from Block 4, the data suggests a higher proportion of selections from disadvantageous decks. However, since there was no significant interaction between the Selection Blocks and Category change, we have to conclude that the category change did not have a statistically significant effect as assessed in this experiment. However, there is a clear trend that is showing that before shifting reward/punishment schedules, the first 100 trials, the mean response generally reflects more advantageous choices whereas after the shift, the means reflect an increase in the selection of disadvantageous choices.

The most important observation is that after the change, participants do not appear to recover or readjust, a finding that would be expected if SMs had been established in Phase 1 and then were operating counterproductively in Phase 2. Instead, their responses show a trend of selections from the 'risky' decks. This, combined with the subjective response data, suggests that participant never fully attain the underlying rules of the task consciously, a result that is consistent with the proposal that the implicit influence of the SM attached or associated with the initial phase of the task interfere with learning. Any SMs which were learned on the previous 100 trials would have guided the selection choices away from the decks A and B and towards the decks C and D. In the new situation after the change in the reward/punishment schedule, the SM system would thus continue to guide the choices towards the decks C and D.

The most important finding is that redundant feedback it would appear, did have an effect on participants' conscious knowledge of the task in that no one appeared to have reached conceptual stage – unlike other findings (Bechara, Damasio, Tranel, & Damasio, 1997a). There are two important conclusions from the behavioural results. First, the participants do not appear to learn the rules of the task explicitly; if they did, then the change on the reward/punishment schedule would have been expected to trigger a rapid bias towards the advantageous decks. Second, if a SM system was in operation, then when faced with different conditions that share the same solution structure, this does not generalize its learning but, instead, hinders new learning by biasing the decision making towards the disadvantageous choices. The behavioural data are thus consistent with the operation of SMs. The EEG data strengthens this proposal.

The EEG data analysed on three electrode sites, F3, FZ and F4, or left, mid and right frontal respectively, indicated, in line with hypothesis, a significant interaction between electrode position and response selection combined with a paired comparison at significance ( $p = 0.05$ ). This shows, for the first time, an important psychophysiological marker that distinguishes between advantageous and disadvantageous decisions before they are enacted and this could be an EEG measure of the activity of the SM. This is an important supporting finding for the SM hypothesis as well as an important additional measure of QASA. If reliably found in larger groups, measures of SM in EEG that can indicate 400ms prior to a decision being enacted whether the decision is likely to be advantageous or not have some obvious applications. To mention an example, a delay may be introduced in some of the important weapon controls in a military aircraft where, for example, the pilot is about to fire at the wrong people. However, this is still not possible as fast, on-line, data analysis are required for this to be possible.

Interestingly, post-hoc analysis revealed a similar difference and direction of differences between the FZ and F3 for both advantageous and disadvantageous response selections. However, as expected the means indicated a lower alpha power preceding the disadvantageous response selection as compared to advantageous response selections. A difference was found for the FZ electrode, which did significantly distinguish between advantageous and disadvantageous choices with the alpha suppression more pronounced for disadvantageous response selections. As was discussed in the introduction above (section 4.1.1), it was expected that a relatively higher activity should reflect an SM signal that is attempting to inhibit and ultimately biasing behaviour away from what is intended. We argued that attempting to bias or stop a behaviour already initiated might require stronger inhibiting neural activation

than just allow the behaviour to continue unabated. The finding of Lower Alpha wave levels preceding risky choices compared with safe choices, which as discussed in the introduction indicate higher levels of activity of the underlying neural circuits, seems to support this view.

There could well be the same neural circuits activations underlying the SM system conveying the information on choices in terms of relative intensity associated with each choice in the mid frontal and left lateral areas of the brain (it is worth noting that 9 out of 11 participant were right handed hence a greater involvement of the left frontal hemisphere would be expected); the latter mainly involved in organizing the choices in terms of relative neural circuit activation intensity to other choices; in essence biasing decisions towards the ones least inhibited. As mentioned in the previous chapter (section 3.1.4, paragraph 5) the mid frontal areas, especially the ACC, is involved in the integration of multiple decision parameters (Kennerley, Behrens & Wallis, 2011). The findings are in agreement with this and suggests that there may be an inhibiting neural activation associated with both response selections, advantageous and disadvantageous, however, in a sense, the advantageous responses are inhibited less and the relative valuation of these parameters is processed in the mid frontal area. This makes sense since participants may have an inhibiting reaction, or anxiety, associated with both choices as long as the knowledge remain implicit and is not fully realized. We can tentatively suggest at this point that the operations of the SM reflected in the relative difference between alpha power intensities associated with each choice with relatively greater alpha suppression representing the inhibiting biasing SM and lower relative Alpha suppression representing the motivating biasing SM.

As expected, this difference was not found on the second hundred trials with the reverse-learning condition. There was a difference found on the recording between FZ and F3 which was similar to the one found on the pre-change condition. This may represent the involvement of medial frontal cortex in ambiguous situations as found in other studies (Stern, Gonzalez, Welsh & Taylor 2010;) However and most importantly, the EEG data failed to distinguish between the response selections indicating the absence of systematic linkages between SMs and responses.

The results from this experiment are largely congruent with previous studies (i.e. Damasio 1994, p. 31-32; Bechara & Damasio, 2005) as well as other neuropsychological studies that delineate the functions of frontal and pre-frontal lobes (i.e. Kennerley et al., 2011). To the authors knowledge, this is the first time SM400 has been related to decision making anywhere in literature. If this is validated by other, independent studies, then it may turn out to be an extremely useful measure of decision-making in a wide variety of paradigms.

A particularly interesting implication from our findings is that now it suggests the possibility of investigating the EEG correlates of SM (henceforth referred to as SM400 for Somatic Marker 400-300 milliseconds prior to response) under different task conditions. For example, how would SM400 behave under conditions, such as manipulating feedback or under conditions of high or low emotional arousal? In the next experiment, we will investigate whether and how the SM400 modulates when the task environment includes deliberately false information.

## Chapter 5 – Dissociating Stimulus Response Association

### Learning with Somatic Markers

#### 5.1 INTRODUCTION

As briefly outlined in Chapter 3 (see section 3.1.7.4), there is an ongoing debate about the validity of the explanation of the Somatic Marker Hypothesis as opposed to Stimulus Response Association Learning (Kringelbach & Rolls 2004). The core of the debate involves two related but somewhat different ideas.

On the one hand, Damasio, Bechara, and colleagues support the idea that the impairment of ventro-medial Pre-Frontal Cortex patients (vmPFC) on the performance of the Iowa Gambling Task suggests the impairment of a crude emotional signal that is sensitive to the long-term consequences of decisions. Based on previous experience, the affective components associated with each possible outcome, which underlie the Somatic Markers, bias the decision making processes towards those marked with positive affective markers and away from those with negative ones (Damasio, 1994, 1999; Bechara, Damasio, Damasio & Anderson 1994, 1996 – same paper). On the other hand, there is compelling evidence from the research work of Rolls and colleagues which suggests that results from IGT may well be explained by a stimulus response association type learning, underlined by the modular activity of various populations of neurons within the Orbito-Frontal neural circuits, which renders input from the body proper as superfluous (Kringelbach & Rolls 2004; Rolls & Grabenhorst 2008). Primary (unlearned) and secondary (learned) emotional stimuli are represented by different Orbito-Frontal structures in accordance with the modality of the reinforcer. According to Kringelbach & Rolls (2004), the

multistage evaluations and processing that follow, determine the behaviours selected, the feelings associated with them and the autonomic responses.

The main source of conflict between these two positions is the extent of the contributions to the OFC and PFC processes from the peripheral and visceral neural pathways; central in the Somatic Marker hypothesis but superfluous according to Kringelbach and Rolls (2004). Although the inclusion of the as-if body loop (see section 3.1.7.3 in Chapter 3) in the Somatic Marker hypothesis does suggest that input from the body is not always necessary hence somewhat resolving the discrepancy, there remains some criticism with regard to the specificity of these neural circuits and, furthermore, that it makes the SM hypothesis rather difficult to falsify. For example, if it was found that absence of the SCR prior to making risky choices does not lead to impaired performance in IGT – as the Somatic Marker hypothesis would predict - than the as-if body loop could always be invoked as a likely explanation. On the other hand, even if input from the body might be a logically superfluous requirement, it does not exclude the possibility that it is nevertheless involved, as has been evidenced by the SCR measurements which indicate a correlated somatic state activation linked to and predicting the performance on the IGT (Damasio 1994).

Furthermore, Kringelbach and Rolls present their view of the functioning of the OFC as an alternative to the Somatic Marker hypothesis asserting that the latter merely sees the OFC as a contributor to the somatic markers whereas instead, Kringelbach and Rolls argue, OFC is mainly involved in “*representing the reward and punishment value of primary (unlearned) reinforcing stimuli and in rapid reversal of stimulus-reinforcement associations*” (Kringelbach and Rolls 2004). However, if we consider both views within the context of Panksepp (2004) theory of brain organization and Kahneman’s Two Systems theory, both discussed in Chapter 3,

it can be argued that instead of being alternatives of each other the Somatic Marker and the Stimulus-Reinforcer hypothesis are rather complementary.

As it will be argued, both explanations can be brought together and indeed provide supporting evidence for Panksepp's (2004) theory of brain organization along the State versus Channel functioning (see section 3.1.4.2 in Chapter 3) as well as the two systems theory, System I and II (Kahneman 2001). The evidence supporting both positions on the functioning of the OFC has been discussed at some length before (see sections 3.1.7.1 to 3.1.7.4 in Chapter 3). To briefly recap, the SM theory posits that the neural systems underlying SM signals, especially vmPFC, are mainly concerned with long-term outcomes. When the SM system malfunctions, such as due to an injury to the relating neural circuits, the resulting effect in cognitive functioning is, what has been termed, myopia for the future (Bechara, Damasio, Damasio & Anderson 1994, 1996). Alternatively, the finding that people with damaged vmPFC are impaired in the performance of IGT task has been linked to the effects of the immediate feedback from each card selection, which provides the conditions for stimulus-reinforcement association learning (reinforcement learning for short) (Fellows & Farah 2003; Berlin, Rolls & Kischka 2004; Deco & Rolls 2005; Simmons & Richmond 2008; Rolls 2004; Rolls 2005).

The description of the OFC functioning by Kringelbach & Rolls (2004) shows the capability of the OFC to engage in quite detailed multileveled processing, which is consistent with Panksepp's description of the Channel functioning and Kahneman's description of System II functioning (as outlined in Chapter 3). Whereas the description of the Somatic Markers as crude and biasing emotional signals by Damasio (1994) is, in turn, consistent with Panksepp's description of the State functioning and Kahneman's description of System I functioning. This suggests that

both modes of processing in the OFC, the crude biasing emotional signal and the ability to represent and rapidly reverse (when required) stimulus-response associations, may be present and can, consistent with Panksepp's and Kahneman's theories, operate either independently of each other or in parallel.

In the following experiment we seek direct evidence that these different explanations of the OFC involvement on the performance in IGT are not competing, but are complementary, both describing different aspects of related but distinct cognitive processes as generally depicted by both Panksepp and Kahneman.

If the idea of two separate systems that converge in OFC is correct, then it is possible to modify the IGT task in a way so that only one of the systems is affected, specifically the Somatic Marker system. The 'SM400' that was identified in the previous experiment, it was hypothesized, was a reflection of the Somatic Markers, in which case, if the conditions for the Somatic Markers to form were removed, then we would predict that this would also be reflected in the absence of the SM400. This question can be tested within the current IGT paradigm by modifying the task so that the immediate and long-term feedbacks are separately manipulated. The goal of the IGT modification would be to retain the conditions for stimulus-response association learning unchanged, while at the same time changing specific aspects of the task that are most likely to affect the Somatic Markers processes. As will be described below, the most likely way to achieve this is in modifying the Long-Term feedback group (see section 4.2.1.4 in Chapter 4 for a detailed definition of Long-Term and Immediate feedback groups).

In the previous experiment of the IGT (Chapter 4), two levels of feedback mechanisms were distinguished (Figure 5.1). There is one level with immediate feedback that reflects instantly the choices made, the feedback presented after each

card selection, and another feedback group which is related to the long-term outcomes, the running sums in bars and numbers which track the performance over time. It is most likely that the Somatic Marker processes would be affected if we modify the long-term feedback so that it is correctly related to immediate feedback. If the choices made do not reflect the long-term outcome, then there would be no reason for the somatic markers to form and guide those choices since the long-term outcome would be roughly similar whatever the choice.

For example, what would be expected if the long-term feedback mechanisms were modified not to show the correct running sum but instead an ever increasing sum which ever choice is made? In other words, if the task was modified so that the losses associated with each card selection do not go into the calculation of long-term feedbacks, just the winnings? This would create a dissociation between long term outcomes, which would not be fully related to the choices, and the immediate feedback related learning, whose conditions are still identical as in the previous experiment. A crucial element of this paradigm is that an emotionally negative aspect of the long-term feedback is removed, thus mimicking a situation whereby the long-term consequences do not accurately reflect immediate choices. There are several possible outcomes.

One outcome is, we would expect that SM400, which, if related to Somatic Markers is also related to long-term outcomes, to be unable to distinguish between the selection responses since the main conditions for it to appear are not present. It would be expected that immediate feedback learning mechanisms, as described by Roll (2004; 2005) would nevertheless facilitate learning and we should be able to see a normal behavioural performance in the absence of the SM400. If, on the other hand, the SM400 is present regardless of the manipulation of the long-term outcome

feedback, then we might be forced to suggest that SM400 is not related to the Somatic Markers and that the most likely explanation is that it is related to immediate feedback learning mechanisms.

There are two further possibilities, first, the SM400 can distinguish between advantageous and disadvantageous selection responses but the behavioural performance does not show a significant increase in learning or, second, the SM400 is not present and there is also no behavioural learning. In the first case we can conclude that the SM400 is not related to Somatic Markers nor Reinforcement Learning and a different explanation must be investigated. In the second case, if the SM400 fails to distinguish between the selection responses and this also is reflected in behaviour, then this should be strong support for the SM hypothesis and the role of neural systems underlying SM400 event would be largely congruent with Damasio's hypothesis. Evidence discussed in the previous two chapters including this one strongly supports the latter possibility.

## 5.2 EXPERIMENT 3: IS SM400 RELATED TO SOMATIC MARKERS OR REINFORCEMENT LEARNING?

### *5.2.1 Method*

#### *5.2.1.1 Participants*

Twenty-six participants were randomly selected (opportunity sampling) mainly from students of the first, second and third year of the psychology course at the University of Gloucestershire (mean age = 24.85, SD = 8.40, 13 female, 24 right handed).

A subsample of this group, a total of 16, were subjected to a 128-channel EEG recording while completing the task (mean age = 27.13, SD = 10.13, 10 male, 1 left handed). All participants signed a consent form accepted by the Ministry of Defence Research Ethics Committee (see Appendix A for the form) prior to taking part in the study. Participants were not offered a monetary reward for participating in the study and were made aware of their right to withdraw at any time without an explanation required.

#### *5.2.1.2 Materials*

The same materials were used as in experiment 2.

##### Apparatus

The same basic equipment were used as in experiment 2. There was one change in feedback in the feedback in the main experiment and one additional question was added (See section 5.2.4 below).

##### EEG Recording

The same recording equipment was used as in experiment 2.

#### *5.2.1.3 Design*

The same design was used as in experiment 2 with one exception. Unbeknown to the participants, the Long-Term Feedback, which were the Graphs and the Total tally (see figure 5.1) was manipulated so that the losses were not counted but only the winnings. In this way, it was ensured that the decisions made were not linked to the long-term performance in the IGT. In these conditions it is expected that Somatic Markers would not be able to mark the choices as risky or safe and that should be reflected by

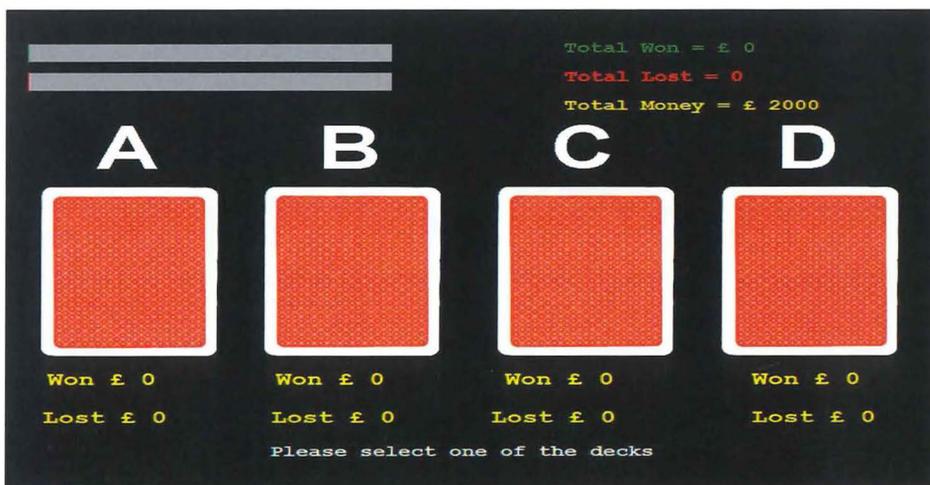
an absence of the SM400, though implicit learning based on immediate feedback, in theory, can.

#### - 5.2.4 Procedure

The same procedure was used as in experiment 2.

#### Iowa Gambling Task (computerized version)

The IGT was the same as in experiment 2 with one change in feedback. The Long-Term feedback was manipulated so that the losses were not added resulting in an ever-increasing amount of money reflected in the Total tally and the Graph bars (Figure 5.1). Also, at the end of the experiment, participants were asked the question: Did you notice any inconsistency on the feedback? This question intended to gauge the participants' conscious awareness of the false feedback.



*Figure 5.1: IGT Decks Arrangement.* Nothing was changed with the exception of the “Total Money” and the Graphs (the two bars on the upper left), which did not subtract the losses therefore resulting in an incorrect (positive) feedback.

#### 5.2.2 Results

This section will be divided into two further subsections: Analysis of Behavioural Data and Analysis of EEG data.

### 5.2.2.1 Behavioural Analysis

Performance score on the IGT was split into five equal blocks of twenty card selections for the first hundred trials and the same for the second hundred trials. For each block, a net score was calculated based on the number of card selections from the advantageous decks (C + D in the first part of the experiment) minus the number of card selections from the disadvantageous decks (A + B), so that the Calculated Score = (C + D) – (A + B). Thus, a positive score reflects a higher ratio of selection from the advantageous decks and a negative score a higher ratio of selection from the disadvantageous decks. A zero score means that selections were equal on both, advantageous and disadvantageous decks. This is reversed on the second part of the experiment, after Category Change since the advantageous decks become disadvantageous and vice versa.

Table 5.1 shows the mean and standard deviation for each for each of Block Selection for before and after category change. Unlike the table 4.1 in the previous experiment, the table below suggest an increasing trend for selection of disadvantageous choices for both Phases. Especially, pre-change shows tendency of selection on disadvantageous decks and not 'learn'.

<b>Means and Standard Deviations of the First and Second 100 Trials (N = 26)</b>				
<b>Trials</b>	<b>Before Category Change</b>		<b>After Category Change</b>	
	<b>Mean</b>	<b>SD</b>	<b>Mean</b>	<b>SD</b>
<b>1 - 20</b>	<b>-1.00</b>	<b>6.20</b>	<b>1.08</b>	<b>11.26</b>
<b>21 - 40</b>	<b>-1.69</b>	<b>5.70</b>	<b>2.31</b>	<b>9.69</b>
<b>41 - 60</b>	<b>-1.69</b>	<b>3.78</b>	<b>-0.15</b>	<b>8.27</b>
<b>61 - 80</b>	<b>-3.77</b>	<b>6.21</b>	<b>0.69</b>	<b>9.00</b>
<b>81 - 100</b>	<b>-1.54</b>	<b>8.16</b>	<b>-2.31</b>	<b>9.10</b>

*Table 5.1: Means and Standard Deviations for the First and Second 100 Trials.* Means and Standard Deviations for the first and second 100 trials, grouped in sets of 20 trials. The distribution of means show an increasing trend toward disadvantageous choices in the first 100 trials, but not so in the second 100 trials.



*Graph 5.1: Means of Pre and After Category Change with SE Bars (outliers corrected).* Responses below zero mean that the proportion of choices from disadvantageous decks (risky) is higher than those from advantageous decks (safe). There is a downward trend toward selecting disadvantageous responses in both phases. The most noticeable aspect of the graph is that in Phase 1, participants' appear not to have learned.

Before and after the category change, participants' responses show a trend of responses moving towards disadvantageous with the Phase 2 starting at a higher proportion of advantageous choices (Graph 5.1). The graph suggest that participants selected generally more from risky decks in Phase 1 and as the reward/punishment contingencies shifted, participants selected initially more from safe decks (previously risky) but with a clear trend towards selecting risky decks again. This suggests that overall, participants were influenced by positive long-term feedback (since the losses were not added, then selecting from risky decks leads to a higher reward).

Responses were subjected to a repeated measures two-way analysis of variance (ANOVA) with five levels of trials Selection Blocks (each block was the mean of the 20 trials in a successive fashion starting from the first Selection Block 1 to 20) and two levels of before and after the category change, Phase 1 and 2.

Using Boxplots, outliers were detected in Selection Blocks 1, 2, 3 and 5 for before category change and 3 and 4 for after category change. The outliers were replaced with the value closest to the outlier. Also, the assumption of the normal distribution of Selection Blocks 2 and 5 Phase 1 were violated as assessed by Shapiro-Wilk test ( $p < 0.05$ ) all the other levels were normally distributed. The assumption of sphericity was also violated for the interaction but not for the main effects, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ); hence Greenhouse-Geisser correction was applied to the analysis accordingly.

There was no statistically significant interaction. There was a main effect of Phases which showed that there was a statistically significant difference between Phase 1 and Phase 2,  $F(1, 25) = 5.54$ ,  $p < .03$ ,  $\eta^2 = 0.18$ . *Post-hoc* analysis with a Bonferroni adjustment revealed that response scores from Phase 2 did statistically significantly increase compared with Phase 1 (2.75 (95% CI, 0.34 to 5.16)). This suggests that participants were selecting more from safe decks on the second half after category change.

#### Subjective data

The answers were inspected to see whether at any point the participants said anything meaning that decks A and B were risky or bad or any other similar word, or that C and D were Safe or Good or any other similar word (see Appendix CD for the data). The evaluation of participants' answers to the two questions revealed that the participants did not reach the conceptual stage in either phase of the modified IGT task.

On the first trial blocks, most participants would express positive feelings about the game and some degree of interest or curiosity. One of the participants for

example wrote in response to the question on how they felt about the game “*It will be more interesting when I can figure out the system and then beat it; more money !*”. As the task progressed, the same participant wrote in response to the same question after the trial blocks 50 to 60 and 60 to 70 “*Frustrated*” and “*Still frustrated...*” respectively and around the trial 90 “*Annoyed*”. Other participants went through a similar trend, showing an interest at the beginning of the task and getting increasingly frustrated, annoyed or bored towards the end of the task. Many of the participants were looking for some kind of trend involving selections from all the deck. A typical method they looked for was some ordering of the selection like “a,b,c,d” then “b,d,c,a” or similar. Other went from selecting a particular number of times one deck then switch to another. Overall, it was clear from the responses that no participant reached a clear understanding of the rules.

All participants reported that they did not notice anything unusual with the game’s feedback sources. They expressed and were visibly surprised when informed about the feedback inaccuracy built into the task.

#### *5.2.2.2 EEG Data Processing*

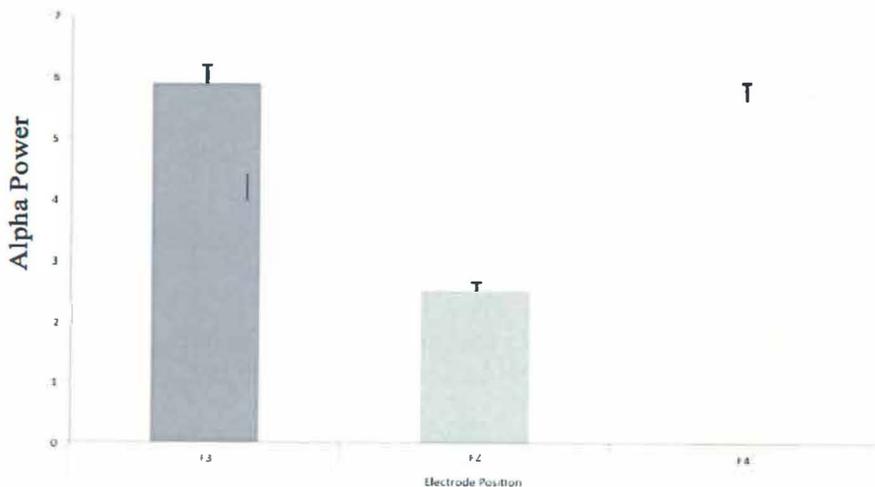
The same data processing of the EEG data was conducted as in experiment 2.

##### *5.2.2.2.1 EEG Analysis for the First 100 Trials –Exploring Somatic Markers’ EEG Correlates*

A 3X2 repeated measures ANOVA (3 electrode positions and 2 choice selections respectively) was conducted to determine whether there were statistically significant differences in EEG alpha mean voltage amplitude for 400 to 300ms prior to response for F3, FZ and F4 electrodes for advantageous and disadvantageous response choices.

Inspection of boxplots revealed outliers. Outliers were normalized to the nearest value (groups FZ negative responses – 1 outlier, FZ positive responses – 3 outliers, FZ negative responses – 3 outliers, F3 negative responses – one outlier, group F3 positive response – 1 outlier) and the data were normally distributed for each level, as assessed by boxplot and Shapiro-Wilk test ( $p < 0.05$ ), respectively. The assumption of sphericity was not violated for the main effects but was violated for the interaction, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Greenhouse-Geisser correction was applied to the data accordingly. No significant interaction was found.

A significant main effect of electrode position was found  $F(2, 30) = 4.09, p < 0.04$ , partial  $\eta^2 = .21$ , with alpha amplitude decreasing for electrodes FZ ( $M = 2.50$ ) when compared to F3 and F4 electrodes ( $M = 5.90$  and  $M = 5.60$  respectively) (Graph 5.2). Post hoc tests using the Bonferroni correction did not reach significance with the difference between FZ and F3 approaching significance ( $p = .06$ ).



Graph 5.2: EEG Mean Alpha Power for F3, FZ and F4 Electrodes (CI 95 %). The biggest decrease of alpha power is found on the FZ

#### *5.2.2.2.2 EEG Analysis for the Second 100 Trials – Exploring Somatic Markers' EEG Correlates*

A 3X2 repeated measures ANOVA (3 electrode positions and 2 choice selections respectively) was conducted to determine whether there were statistically significant differences in EEG alpha mean voltage amplitude for 400 to 300ms prior to response for F3, FZ and F4 electrodes for advantageous and disadvantageous response choices. Inspection of studentized residuals revealed outliers which were normalized to the nearest value (groups FZ negative responses – 1 outlier, FZ Positive responses – one outlier, F3 positive responses – 1 outlier) and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ( $p > 0.05$ ), respectively. The assumption of sphericity was not violated for the main effects but was violated for the interaction, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ) hence Greenhouse-Geisser correction was applied. No significant interaction was found. Also, no significant main effects were found.

### 5.3 DISCUSSION

Introducing an element of long-term incorrect feedback, which appears to have not been consciously apprehended, impedes and somewhat reverses the learning curve that was observed in the previous experiment. Unlike what was observed in chapter 4, in this modification of IGT the participants' behavioural data shows a trend of selection towards risky choices. The long-term incorrect feedback did appear to have an effect as participants initially (Phase 1) selected more from the risky decks on all trial blocks. An important aspect of manipulating the long-term feedback was to remove the negative emotional element from it while retaining it in the immediate

feedback sources. Participants appear to have not made the distinction between the advantageous and disadvantageous decks either consciously or unconsciously and the trend in both, pre and after category change was to move towards more selections from the risky decks as the task continued. These results support the SM hypothesis, especially its main tenet which states that long-term learning, associated with the somatic marker, is necessary for the learning to take place in the IGT.

As was mentioned in the introduction, there were four possible outcomes. The first was that SM400 did not distinguish between choices made but the behavioural data shows that learning took place, second that SM400 is present regardless of the manipulation of the long-term outcome feedback, third that SM400 can distinguish between advantageous and disadvantageous selection responses but the behavioural performance does not show a significant increase in learning and last that SM400 is not present and there is also no behavioural learning. The data supports the last proposition, that modifying the Long-Term feedback led to the failure of SM400 to reflect the risk or safety of the choices and this was also reflected in the behavioural data. This data are generally in support for the Somatic Marker hypothesis' assertion that an emotional signal that reflects the long-term consequences of the decisions and located around the frontal central areas of the brain, may be an important component of learning and subsequent decision making and behaviours.

The data do not support Roll's theory which suggest that learning in the IGT task is a consequence of immediate feedback, reinforcement learning. There are two crucial distinctions between the immediate feedback and long-term feedback in this modification of the IGT task, the time the feedback stays on screen and the amount of cognitive processing needed to determine whether the feedback was a negative one or a positive one. In the immediate feedback, participants are presented with the

consequences of their decisions instantly but they stay on screen only for a short time, 1 second. Also, the cognitive processing requirements to determine whether the selection they made was a negative or a positive one is minimal, and easy to make, they only have to see which number is bigger, the losses or the winnings, which is clear in all cases. Whereas in the Long-Term feedback groups, the total amount stays on screen throughout the task, however, the amount of the calculations needed to determine whether the selection was good or bad is greater. First they need to remember what the amount previous to a choice being made was before each time they make a selection in order to determine whether it is increasing or decreasing. Second, in order to determine by what amount, they have to make the calculation from the immediate feedback, Winnings – Losses, then add this to the current Total. Arguably, this is the reason why participants were not able to notice that the feedback had been manipulated to show an incorrect sum. Three of the participants that were asked, how they thought they did in the game, however, expressed a satisfaction with their performance saying that overall they had more money than what they started with, which suggests that the long-term feedback was indeed noticed and processed.

It is difficult to explain the results from this experiment within Roll's framework, although in reality, an interplay between the two, immediate and long-term feedback, may be not just possible but highly likely. However, considering that the immediate feedback mechanisms in the task remained exactly the same as in the previous version and as in the original task, and yet we observe no learning. Then the logical conclusion is that, at least, other elements are also involved, in this case the data suggest Somatic Markers.

Literature discussed so far has identified opposing arguments as to how learning in IGT, as observed from behavioural responses, takes place and the

mechanisms involved, but on the whole there are no arguments against that in general, learning does take place in IGT (Damasio, 1994, 1999; Bechara, et al., 1994; Kringelbach & Rolls, 2004; Rolls & Grabenhorst, 2008). Since dissociating long-term feedback from immediate choices, in the sense that the long term outcomes did not accurately reflect the reward/punishment schedules of the choices, led to participants not learning the task and also to an absence of the SM400, then the most likely explanation is that SM400 is related to the long term outcomes and that it is an necessary component for learning to take place. This situation may reflect real life cases whereby some mechanism that is meant to provide feedback on a state of a system, malfunctions, which may lead to errors. An example of just such a problem was described in Chapter 3 (section 3.1.7).

The EEG recording also supports the behavioural results. Unlike in the previous experiment, in this one, frontal electrodes did not distinguish between the advantageous and disadvantageous choices. Taken together with the behavioural results, EEG analysis of the frontal electrodes support the idea that SM did not create or function given the manipulation of the long-term feedback.

## **Chapter 6 – Dissociating Anticipatory Anxiety from Somatic Markers and their Relation to SM400**

### 6.1 INTRODUCTION

In the previous chapter we were able to provide further support that the SM400 is more likely to reflect the emotional foresight sensitive to the long-term effects associated with decisions made. However, there is one further aspect related to this claim which if ruled out will strengthen the support for the hypothesis that SM400 is indeed related to the long-term decision making and therefore Somatic Markers. There is a possibility that in the original Iowa Gambling Task (IGT), the Skin Conductance Responses found by Damasio and colleagues (eg. Damasio et.al., 1991) as well as the SM400 detected in the first experiment of this series may be related to anticipatory anxiety linked with the responses to the risky decks since they have larger punishment schedules than the safe decks. In this chapter we will attempt to provide evidence that SM400 reflects Somatic Markers and not Anticipatory Anxiety.

As the research discussed below suggests, anticipatory anxiety is linked to general avoidance, risk-averse behaviour, the extent of engaging in which differs in different people (Maner, Richey, Cromer, Mallott, Lejuez, Joiner & Schmidt, 2007) and there is no evidence to suggest that this is due to different functioning of the Somatic Markers system. This type of behaviour can potentially provide an alternative explanation to Somatic Marker hypothesis with regard to the performance of participants in the IGT; participants may simply guide their decisions on a general tendency to avoiding punishments rather than having a feeling of which decision is more advantageous and which is not. This explanation is markedly different from the

Somatic Marker hypothesis since the latter supports the view that the Somatic Markers provide emotional insights into which decisions are advantageous and which are not whereas the former suggests that decisions can also be explained by general tendencies and personality traits (Barret & Armony, 2006). As we will see, these explanations are not incompatible since they can both affect decisions in different ways, however, it is necessary to investigate which of the two the SM400 represents. The distinction is crucial since both Somatic Markers and Anticipatory Anxiety appear to share many of their underlying neural circuits.

Literature on the subject of anticipatory anxiety reveals that it involves several cognitive and neural aspects which overlap with the Somatic Marker Hypothesis, for example, a future oriented cognitive state, negative affect as well as increased emotional and autonomic system arousal (Chua, Krams, Toni, Passingham & Dolan 1999). Furthermore, Chua and colleagues have correlated (using a shock vs no shock condition and low vs. high distraction test) several frontal and limbic areas of the brain, also related to the Somatic Marker Hypothesis, with the Anticipatory Anxiety, such as right superior temporal sulcus, left fusiform, and left anterior cingulate whereas Tillfors, Furmark, Marteinsdottir & Fredrikson (2002) have also implicated right dorsolateral prefrontal cortex, left inferior temporal cortex, as well as the amygdaloid-hippocampal region. Additionally, Grillon, Lissek, Rabin, McDowell, Dvir, & Pine (2008) have found that inability to predict aversive events can lead to a greater physical startle reflex, especially in people with Panic Disorder who may be overly sensitive to unpredictable aversive events, such as a recurring future panic attack for example.

Other studies show that anticipatory anxiety can play a, often crucial, biasing role in decision-making tasks, not unlike the Somatic Markers. Maner, Richey,

Cromer, Mallott, Lejuez, Joiner & Schmidt (2007) ran three studies to investigate the link between trait anxiety and the tendency to engage in risk-avoidant decision-making. Comparing people with clinical disorders as well as healthy controls against people with anxiety disorders, Maner et al., (2007) found that the latter were significantly more likely to engage in risk-averse behaviours. People that are heavily biased towards risk-averse behaviours could also conceivably perform well in Iowa Gambling Task, but, unlike what Somatic Markers hypothesis postulates, it does not necessarily mean they have an emotional understanding of the task in the same way.

Furthermore, Barret & Armony (2006) investigated the modulating effects of trait anxiety on cognitive performance and autonomic activity during an anticipatory anxiety task. Participants were asked and completed a letter-size decision-making task while experimenters conditioned the participants to create an association between a particular color (background color within which the letters were presented) and aversive noise stimuli. After sensitization, participants completed two further experiments where in one, the aversive stimulus was presented at a rate unpredictable to the participants and another one in which the aversive stimuli was not presented at all. They reported that during the first experiment participants elicited a significantly greater Skin Conductance Response (SCR) in response to the color paired with the aversive stimuli as compared to the second experiment. This suggests that SCRs responses, which are a central measure in Somatic Marker studies implicating the involvement of the body in the decision making processes, may also be involved in anticipation of aversive stimulus. Additionally, Barret and Armony also reported that high trait anxiety could predict the speed of response in the decision making task, with those with a higher trait anxiety being faster whereas those with low trait anxiety being slower.

More specifically, Grupe, Oathes & Nitschke (2012) suggested a delineation of the anticipatory anxiety into Immediate and Sustained anticipatory anxiety and showed that each mapped to related but different neural circuits. Especially the Immediate anticipatory anxiety, which is more likely to relate to the dynamic nature of the Somatic Marker system, appeared to recruit neural circuits, which are also important in the Somatic Marker hypothesis such as, the orbitofrontal cortex and pregenual anterior cingulate cortex, as well as the amygdala. Carlson, Greenberg, Rubin & Mujica-Parodi (2011) also find support for related neural circuits, such as anterior insula, as being important to anticipatory anxiety. Furthermore, Brühl, Rufer, Delsignore, Kaffenberger, Jäncke, & Herwig (2011) found that during the anticipation of negative emotional stimuli brain activity in patients with Social Anxiety Disorder was increased in the upper midbrain/dorsal thalamus, the amygdala, and in temporo-occipital and parietal regions as compared to control subjects.

These studies raise the possibility that the behaviour and EEG correlates observed during participation in the IGT task (Chapter 4) may be explained differently. If participants create an anxiety reaction to the bad decks, specifically to the larger punishments, they may start to display general risk-averse behaviours, which would explain why they tend to veer off those choices and prefer the alternatives. In this case, the SM400 signal may be reflecting an Anticipatory Anxiety response, which is not necessarily associated with a feeling that reflects long-term outcomes. Results from experiment 3 do provide some evidence to the contrary. The SM400 appears to be related to the long-term feedback and disappears when long-term feedback is manipulated to not reflect immediate feedbacks accurately.

In the IGT task, as the participants work their way through the reward/punishment schedules across the decks, it is not inconceivable that the larger

punishments associated with the bad decks may invoke an anticipatory anxiety response leading to generally risk-averse behaviours. In such a scenario, we might expect to see the same behavioural and, quite likely, the activation of the neural patterns as suggested by Chua et al (1999) and Tillfors et al (2002) but, in this case, it would not be related to the decision making in the same way as conceived by Damasio. In other words, the SM400 neural discrimination of safe versus risky choices that was found in the first experiment of this series (Chapter 4), instead of being related to the long-term decision-making, or an emotionally guided foresight of the future consequences associated with present decisions, may instead reflect the more temporally local, risk-averse behaviours that do not necessary involve emotional foresight in the way Damasio describes Somatic Markers. Therefore, the SM400 found in the original administration of IGT could instead be a reflection of an anticipatory anxiety response to the larger punishment schedules in the risky decks.

To exclude, or indeed include, this alternative explanation it is therefore necessary to run a modified version of the original IGT to control more explicitly for the anticipatory anxiety. If IGT could be modified so that the conditions for inducing anticipatory anxiety would be satisfied without compromising the main structure of the task, then we would be able to compare its effects on learning and the SM400 signal. In other words, if two of the decks are associated with a clear, consciously perceived anxiety provoking stimuli and if SM400 appears to reflect this, then this would support the idea that SM400 is linked to Anticipatory Anxiety and not Somatic Markers. The solution found to test for this hypothesis was to introduce into the task a subset of negative and positive image stimuli from the International Affective Picture System with. IAPS images have been used before in similar paradigms to test for

Anticipatory Anxiety (Brühl et al., 2011; Staples, Oathes, Jenson, Schmidt, & Nitschke 2008).

In this experiment, IGT is modified so that it introduces a clear Negative and Positive affective stimuli which would be associated with each choice. As participants make a choice, along with the usual feedbacks, an emotionally potent stimulus would also be presented in the form of an emotionally intense image, Positive or Negative, which will appear at the back of the card instantaneously (see below). Images in the Phase 1 are aligned incongruently, positive images with decks A and B (risky decks) and negative images with decks C and D (safe decks). The incongruent arrangement in the initial decks is chosen so that it was more likely to interfere with learning. In this case, if SM400 emerges as a response to the negative images, then that would bring into question the previous finding that SM400 reflects somatic markers. It should be noted that in the phase two of the task, when the reward/punishment schedules swapped across the decks, then the arrangement between IAPS images and the risky/safe decks become congruent. It is decided to keep the arrangement of the images unchanged since to change the images at that point would give a clear visual clue to the participants of the underlying shift of the reward schedules which would compromise the task.

The negative and positive affective stimulus chosen from the IAPS sets is selected from the extreme ends of the standardized scores in negative and positive arousal/valence dimensions so that an anticipatory anxiety response would be more likely to emerge on the negative images relative to the positive images. As was mentioned above, when the negative images are paired with safe decks in the first phase of the experiment, it is expected that participants will find it harder to learn the rules of the task, hence it is expected that learning will not take place. Additionally,

even in the second phase, when the images are paired congruently (as the reward/punishment schedules shift) it is still expected that the addition of the emotional images in the task will play a disruptive role to the learning process as they divert attentional resources away from the main goal of the task, which is to gain as much money as possible. This is preferable since we are investigating whether SM400 appears in absence of learning and as a response to the anxiety provoking IAPS images.

The reason to use one image alone versus many images is because it is judged that many images containing varying and different content could create too much interference in the task. To compensate, the two images selected will have to be the most representatives of each category. The draw back is that participants might be saturated with one image and the desired emotional effect might therefore be reduced. This is a clear limitation of this paradigm as it stands.

It is expected that a highly negative emotional image, staying on-screen for 1000ms, is likely to induce an anticipatory anxiety response relative to the pleasurable image. In which case, if the SM400 is related to the anticipatory anxiety response and not long-term decision making, than we would be able to find the signal distinguishing between the Negative and Positive sets with the Negative set essentially invoking roughly the same neural response that was detected in SM400 - a significant decrease of Alpha power 400ms prior to making the choices associated with the anxiety provoking, negative images. If, however, the SM400 fails to reflect this difference, than we strengthen the argument that SM400 does reflect the emotionally guided long-term outcomes, or the gut feeling, and is not related to local, immediate feedback anxiety response.

## 6.2 EXPERIMENT 4 – DISSOCIATING ANXIETY RESPONSE FROM SOMATIC MARKER HYPOTHESIS

### 6.2.1 *Method*

#### 6.2.1.1 *Participants*

Thirteen participants were randomly selected (opportunity sampling) mainly from students of the first, second and third year of the psychology course at the University of Gloucestershire (mean age = 22.77, SD = 8.14, 10 female, 12 right handed).

A subsample of this group, a total of 12, were subjected to a 128-channel EEG recording while completing the task (mean age = 22.75, SD = 8.50, 9 female, 1 left handed). All participants signed a consent form accepted by the Ministry of Defence Research Ethics Committee (see Appendix 4 for the form) prior to taking part in the study. Participants were not offered a monetary reward for participating in the study and were made aware of their right to withdraw at any time without an explanation

#### 6.2.1.2 *Materials*

##### Apparatus

The same materials were used as experiment 3 with one addition, two Images selected from IAPS set. Image numbers 3000 and 4664 were chosen with valence and arousal

values of 1.45, 7.26 and 6.61 and 6.72 respectively. The images were chosen so that they were approximately matched in the normative arousal scoring while differing in negative and positive valence scores.

### *6.2.1.3 Design*

The same design was used as in experiment 2 with one addition. Upon selecting a deck, participant were shown one of the two images selected from the IAPS set. In the first 100 trials, the immediate IAPS image feedback associated with the photos was incongruent with the long-term, monetary feedback, and congruent on the second 100 trials – that is on Phase 1 the safe decks had the negative IAPS feedback, while in Phase 2 this was reversed so that the safe decks now had the positive IAPS feedback.

In these conditions it is expected that Somatic Markers would not be able to mark the choices as risky or safe and that should be reflected by an absence of the SM400. If, on the other hand, SM400 is present and discriminates between the negative and positive images, then SM400 is more likely to reflect anticipatory anxiety instead.

### EEG Recording

The same recording equipment was used as in experiment 2.

### *6.2.1.4 Procedure*

The same procedure was used as in experiment 2.

### Iowa Gambling Task (computerized version)

As in the previous paradigm (see Chapter 4, section 4.2.1.4), each time participants selected a card, one of the selected IAPS images was presented on the back of the

selected card as shown below. The photos were kept in the same positions as shown throughout the 200 trials (Figure 6.1, top image).

This means that in the first 100 trials, the immediate IAPS image feedback associated with the photos was incongruent with the long-term, monetary feedback, and congruent on the second 100 trials – that is on Phase 1 the safe decks had the negative IAPS feedback, while in Phase 2 this was reversed so that the safe decks now had the positive IAPS feedback and the risky the negative IAPS feedback.

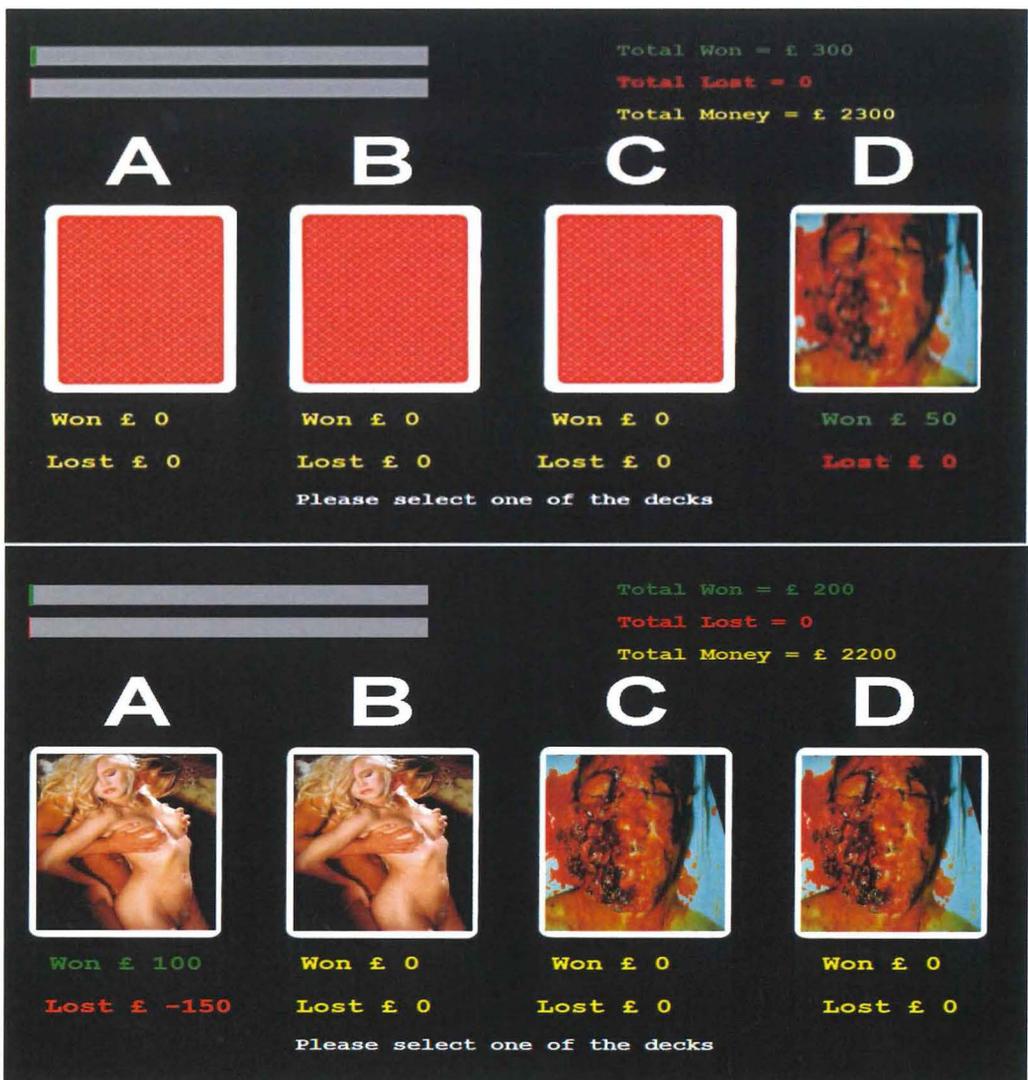


Figure 6.1: The Arrangement of Affective Stimuli and Decks in IGT. The screen capture on the top shows how the participants are exposed to the images after making

a choice, in this case participants has chosen D. On the screen capture on the bottom, the photos are shown on the actual original arrangement for this experiment. The feedback associated with each card selection was kept as shown on the bottom screenshot for all 200 trials.

### *6.2.2 Results*

This section will be divided into two further subsections: Analysis of Behavioural Data and Analysis of EEG data.

#### *6.2.2.1 Behavioural Analysis*

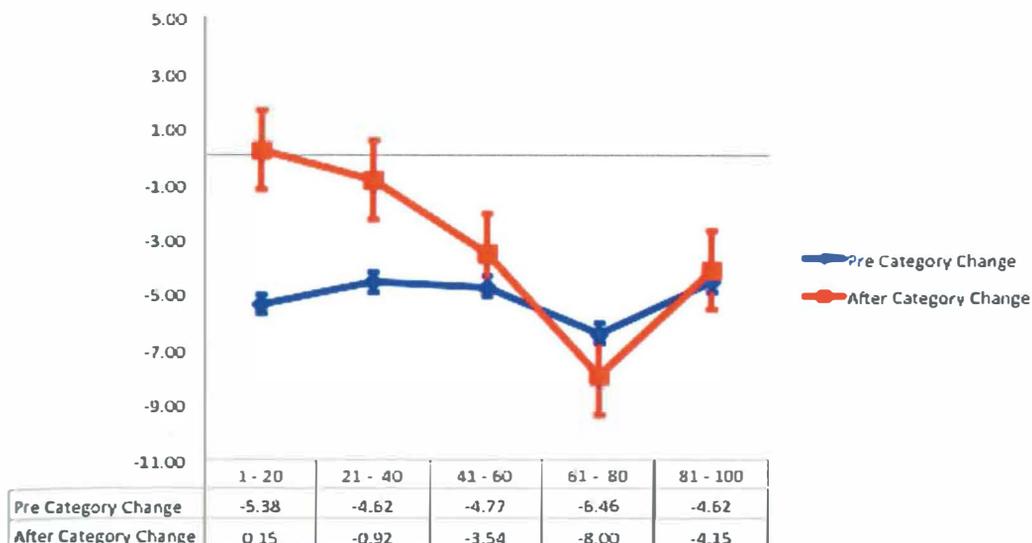
Performance score on the IGT was split into five equal blocks of twenty card selections for the first hundred trials and the same for the second hundred trials. For each block, a net score was calculated based on the number of card selections from the safe decks (C + D in the first part of the experiment) minus the number of card selections from the risky decks (A + B), so that the Calculated Score = (C + D) – (A + B). Thus, a positive score reflects a higher ratio of selection from the advantageous decks and a negative score a higher ratio of selection from the disadvantageous decks. A zero score means that selections were equal on both advantageous and disadvantageous decks. This is reversed on the second part of the experiment, after Category Change since the advantageous decks become disadvantageous and vice versa.

<b>Means and Standard Deviations of the First and Second 100 Trials (N = 13)</b>				
<b><u>Trials</u></b>	<b>Before Category Change</b>		<b>After Category Change</b>	
	<b>Mean</b>	<b>SD</b>	<b>Mean</b>	<b>SD</b>
<b>1 - 20</b>	<b>-5.38</b>	<b>5.74</b>	<b>0.15</b>	<b>8.58</b>
<b>21 - 40</b>	<b>-4.62</b>	<b>6.02</b>	<b>-0.92</b>	<b>4.87</b>
<b>41 - 60</b>	<b>-4.77</b>	<b>5.57</b>	<b>-3.54</b>	<b>6.79</b>
<b>61 - 80</b>	<b>-6.46</b>	<b>5.24</b>	<b>-8.00</b>	<b>6.73</b>
<b>81 - 100</b>	<b>-4.62</b>	<b>10.37</b>	<b>-4.15</b>	<b>7.72</b>

*Table 6.1: Means and Standard Deviations for the First and Second 100 Trials.* Means and Standard Deviations for the first and second 100 trials, grouped in sets of 20 trials. The distribution of means shows that overall participants responded disadvantageously on both categories. Introducing the emotional stimuli has deteriorated the performance.

Table 6.1 shows the mean and standard deviation for each for each of Block Selection for before and after Category Change. The table shows a random behaviour. More specifically, participants appear to respond consistently disadvantageously before and after category change.

Before and after the category change, participants' responses show a trend of responses moving towards disadvantageous with the After Category change starting at a higher proportion of advantageous choices (Graph 6.1). Participants appear to have selected the risky decks (with positive images) in Phase 1 and again, the risky decks (with negative images) in Phase 2. In Phase 2, participants start with selections from safe decks (with positive images now) but select progressively the risky decks (with negative images).



*Graph 6.1: Means of Pre and After Category Change with SE Bars.* Responses below zero mean that the proportion of choices from disadvantageous decks (risky) are higher than those from advantageous decks (safe). There is a trend toward selecting disadvantageous responses on both categories.

Responses were subjected to a two-way repeated measures ANOVA with five levels of trials Selection Blocks (each block was the mean of the 20 trials in a successive fashion starting from the first Selection Block 1 to 20) and two levels of before and after the category change, Phase 1 and 2.

Using Boxplots, outliers were detected in Selection Blocks 1, 2 and 4 for before category change and 4 for after category change. The outliers were replaced with the value closest to the outlier. The assumption of the normal distribution was not violated as assessed by Shapiro-Wilk test ( $p > 0.05$ ). Also, the assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > .05$ ).

There was no statistically significant interaction and there were no significant main effects.

#### Subjective data

The answers were inspected to see whether at any point the participants said anything meaning that decks A and B were risky or bad or any other similar word, or that C and D were Safe or Good or any other similar word (see Appendix for the data). The evaluation of participants' answers to the two questions revealed that the participants did not reach the conceptual stage in either phase of the modified IGT task.

Many participants indicated displeasure about the negatively valenced images using words such as “*gruesome, disturbing, not very pleasant and bloody face*”. As the participants progressed through the task some similar indications, boredom, frustration, annoyance, as in previous tasks started to emerge. One participant also expressed anger.

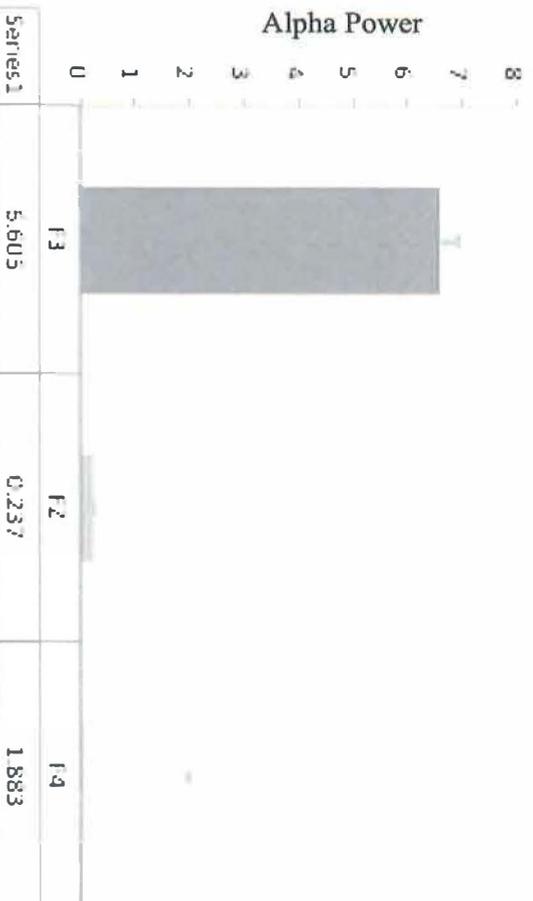
#### *6.2.2.2 EEG Data Processing*

The same data processing of the EEG data was conducted as in experiment 2.

##### *6.2.2.2.1 EEG Analysis for the First 100 Trials – Exploring Somatic Markers' EEG Correlates*

A 3X2 repeated measures ANOVA (3 electrode positions and 2 choice selections – risky (disadvantageous) and safe (advantageous) - respectively), was run to determine whether there were statistically significant differences in EEG alpha mean voltage amplitude for 400 to 300ms prior to response for F3, FZ and F4 electrodes for advantageous and disadvantageous response choices. Inspection of boxplots revealed no outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ( $p > 0.05$ ), respectively. The assumption of sphericity was not violated for the main effects but was violated for the interaction, as assessed

by Mauchly's Test of Sphericity,  $\chi^2(2) = 6.79$ ,  $p = .03$ , hence Greenhouse-Geisser correction was applied. No significant interaction was found.



*Graph 6.2: Mean Alpha Power For Disadvantageous and Advantageous Responses (CI 95 %).* The biggest decrease of alpha power is found on the FZ electrode and the F4 electrode.

A significant main effect of electrode position was found  $F(2, 22) = 4.25$ ,  $p < 0.03$ , partial  $\eta^2 = .28$ , with alpha amplitude decreasing for electrodes FZ and F4 ( $M = .24$  and  $M = 1.88$  respectively) compared to F3 ( $M = 6.61$ ) (Graph 6.2). Post hoc tests using the Bonferroni correction showed a significant decrease in Alpha power from F3 to FZ ( $p < 0.05$ ).

### 6.2.2.2 EEG Analysis for the Second 100 Trials – Exploring Somatic Markers' EEG

#### Correlates

A 3X2 repeated measures ANOVA (3 electrode positions and 2 choice selections respectively) was conducted to determine whether there were statistically significant differences in EEG alpha mean voltage amplitude for 400 to 300ms prior to response for F3, FZ and F4 electrodes for advantageous and disadvantageous response choices.

Inspection of boxplots revealed no outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ( $p < .05$ ), respectively. The assumption of sphericity was not violated as assessed by Mauchly's Test of Sphericity ( $p > .05$ ). No significant interaction was found. Also, no significant main effects were found.

### 6.3 DISCUSSION

The first thing to notice from the results in this experiment, is that the introduction of the emotional images disrupted the learning. This is not unexpected; an added emotional dimension is likely to be distracting and impair learning as has happened here. Most importantly, in accordance with our hypothesis, the data suggests that SM400 is not related to the Anticipatory Anxiety. If the response were only driven by anxiety then participants should have chosen poorly in Phase 1 (since the positive images were paired with the risky decks) and well in Phase 2 since the positive images were paired with the safe decks) and this was not the pattern in Phase 2. Accordingly, the absence of SM400 when the task had not been learned, regardless of the presence of the anxiety provoking stimuli, provides strong support that SM400 does not reflect Anticipatory Anxiety.

In other words, the results of the behavioural data showed that the task was not learned and this was reflected in the EEG recording. The introduction of the emotionally potent images did not lead to a neural discrimination between the Positive and Negative decks at 400 to 300ms prior to making the choice. If it had, then the idea that the SM400 reflect the emotionally guided decision-making would have been refuted and the association would have pointed towards a correlation between the SM400 and an Anticipatory Anxiety response.

However, in this experiment, the images presented in the first 100 trials were arranged incongruently to the riskiness of the decks. In other words, risky decks were paired with the Positive images and safe decks with the Negative images. Therefore an argument can be made that the incongruent nature of arrangement of the images in the first 100 trials impaired the learning in the first 100 trials. The question then arises, what if the emotional stimuli were arranged congruent to the decks on the first 100 trials, would that assist the participants learning? This question will be addressed in the next experiment. We would expect that the introduction of the emotional stimuli, regardless of whether they were congruently or incongruently arranged, would impair learning as they would attract attentional resources away from the task hence impairing performance.

#### 6.4 EXPERIMENT 5 – TESTING THE CONGRUENT ARRANGEMENT OF EMOTIONAL STIMULI AND RISKY/SAFE DECKS IN IGT

##### *6.4.1 Method*

###### *6.4.1.1 Participants*

Twenty-four participants were randomly selected (opportunity sampling) mainly from students of the first, second and third year of the psychology course at the University of Gloucestershire as well as local population (mean age = 30.36, SD = 14.54, 17 female, 22 right handed).

A subsample of this group, a total of 12, were subjected to a 128-channel EEG recording while completing the task (mean age = 37.33, SD = 15.39, 7 female, 1 left handed). All participants signed a consent form accepted by the Ministry of Defence Research Ethics Committee (see Appendix 4 for the form) prior to taking part in the

study. Participants were not offered a monetary reward for participating in the study and were made aware of their right to withdraw at any time without an explanation

#### *6.4.1.2 Materials*

The same materials were used as in experiment 4.

#### *Apparatus*

The same materials were used as in experiment 4 but the images were switched so that in the initial 100 trials, disadvantageous decks were paired with negatively valenced image and positive Decks were paired with the positively valenced image and vice-versa for the next 100 trials (Figure 6.2 below).

#### *EEG Recording*

The same EEG recording equipment was used as in experiment 4.

#### *6.4.1.3 Design*

The same design was used as in experiment 4 with one modification. In the first 100 trials, the immediate IAPS image feedback associated with the photos was now congruent with the long-term, monetary feedback, and incongruent on the second 100 trials – that is on Phase 1 the safe decks had the positive IAPS feedback, while in Phase 2 this was reversed so that the safe decks now had the negative IAPS feedback.

As in the previous experiment, it is expected that Somatic Markers would not be able to mark the choices as risky or safe and that should be reflected by an absence of the SM400. However, it is important to see whether placing the images in a congruent arrangement with regard to the monetary awards in the first 100 trials leads to a different behaviour. Again, as in the previous experiment if SM400 is present and

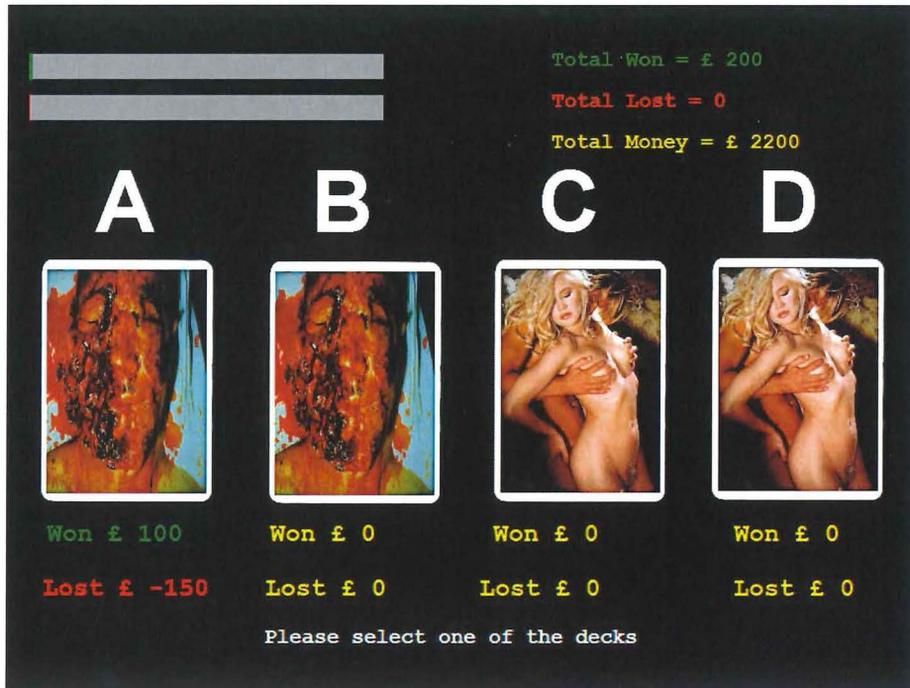
discriminates between the negative and positive images, then SM400 is more likely to reflect anticipatory anxiety instead.

#### *6.4.1.4 Procedure*

The same procedure was used as in experiment 4.

#### *Iowa Gambling Task (computerized version)*

As in the previous paradigm, each time participants select a card, one of the selected IAPS images was presented on the back of the selected card as shown below. The photos were kept in the same positions as shown throughout the 200 trials (Figure 6.2). This means that in the first 100 trials, the immediate feedback associated with the photos were congruent with the long-term monetary feedback – the positive IAPS images were paired with the safe decks and negative images with the risky decks in the first 100 trials – and incongruent in the second 100 trials – positive IAPS images were paired with the risky decks and negative images with the safe decks (Figure 6.2).



*Figure 6.2: The Arrangement of Affective Stimuli Across the Decks in IGT Task.* The IAPS images were arranged so that in the first 100 trials the negatively valenced images appeared on the back of the disadvantageous decks and positively valenced ones on the back of advantageous decks.

#### 6.4.2 Results

This section will be divided into two further subsections: Analysis of Behavioural Data and Analysis of EEG data.

##### 6.4.2.1 Behavioural Analysis

Performance score on the IGT was split into five equal blocks of twenty card selections for the first hundred trials and the same for the second hundred trials. For each block, a net score was calculated based on the number of card selections from the advantageous decks (C + D in the first part of the experiment) minus the number of card selections from the disadvantageous decks (A + B), so that the Calculated Score = (C + D) – (A + B). Thus, a positive score reflects a higher ratio of selection from the advantageous decks and a negative score a higher ratio of selection from the

disadvantageous decks. A zero score means that selections were equal on both, advantageous and disadvantageous decks. This is reversed on the second part of the experiment, after Category Change since the advantageous decks become disadvantageous and vice versa. It is expected that if anxiety is driving the responses then it is expected participants will select from the safe decks in the Phase 1 of the experiment and the risky decks on Phase 2.

<b>Means and Standard Deviations of the First and Second 100 Trials</b>				
<b>(N = 24)</b>				
<b>Trials</b>	<b>Before Category Change</b>		<b>After Category Change</b>	
	<b>Mean</b>	<b>SD</b>	<b>Mean</b>	<b>SD</b>
<b>1 - 20</b>	<b>0.50</b>	<b>5.32</b>	<b>0.58</b>	<b>7.72</b>
<b>21 - 40</b>	<b>-1.42</b>	<b>5.70</b>	<b>0.75</b>	<b>4.52</b>
<b>41 - 60</b>	<b>-0.58</b>	<b>6.45</b>	<b>0.67</b>	<b>7.12</b>
<b>61 - 80</b>	<b>0.92</b>	<b>8.85</b>	<b>1.00</b>	<b>9.83</b>
<b>81 - 100</b>	<b>-0.58</b>	<b>7.19</b>	<b>1.67</b>	<b>9.70</b>

Table 6.2: The Means and Standard Deviations for Before and After Category Change. The table shows the means and standard deviations for each of the blocks of trials for before and after category change. There is no detectable trend on the data.

Table 6.2 shows the mean and standard deviation for each for each of Block Selection for before and after Category Change. The table appears to show a random behaviour. After category change, participants' responses show a trend of responses moving towards advantageous. Before category change the behaviour appears more random but on the whole are biased towards the Advantageous choices (Graph 6.3).



*Graph 6.3: Means of Pre and After Category Change with SE Bars (Outlier Corrected Data).* Responses below zero mean that the proportion of choices from disadvantageous decks (risky) are higher than those from advantageous decks (safe). There is a trend toward selecting advantageous responses after the category change.

Responses were subjected to a repeated measures two-way analysis of variance (ANOVA) with five levels of trials Selection Blocks (each block was the mean of the 20 trials in a successive fashion starting from the first Selection Block 1 to 20) and two levels of before and after the category change, Phase 1 and 2.

Using Boxplots, outliers were detected in Selection Blocks 2 – 2 outliers, and 5 - 4 outliers, for before category change and Selection Blocks 1 – 1 outlier, 2 – 2 outliers and 5 – 1 outlier for after category change. The outliers were replaced with the value closest to the outlier. Also, the assumption of the normal distribution of Selection Block 5 pre Category Change was violated as assessed by Shapiro-Wilk test ( $p < 0.05$ ), all other blocks of trials were normally distributed ( $p > 0.05$ ). The assumption of sphericity was violated for interaction as assessed by Mauchly's Test of Sphericity  $\chi^2(9) = 34.47$ ,  $p = .000$ , hence Greenhouse-Geisser correction was applied.

There was no statistically significant interaction and there were no significant main effects.

#### Subjective data

The answers were inspected to see whether at any point the participants said anything meaning that decks A and B were risky or bad or any other similar word, or that C and D were Safe or Good or any other similar word (see Appendix for the data). The evaluation of participants' answers to the two questions revealed that the participants did not reach the conceptual stage in either phase of the modified IGT task.

The pattern of the responses was largely similar as in the previous version of this task.

#### *6.4.2.2 EEG Data Processing*

The same EEG analysis procedure was used as in experiment 2.

##### *6.4.2.2.1 EEG Analysis for the First 100 Trials – Exploring Somatic Markers' EEG Correlates*

A 3X2 repeated measures ANOVA (3 electrode positions and 2 choice selections respectively) was conducted to determine whether there were statistically significant differences in EEG alpha mean voltage amplitude for 400 to 300ms prior to response for F3, FZ and F4 electrodes for advantageous and disadvantageous response choices. Inspection of boxplot revealed outliers in F3 recording for disadvantageous selections – 1 outlier, F3 recording for advantageous selections – 1 outlier, in F4 recording disadvantageous selections – 1 outlier and F4 recording advantageous selections – 1 outlier. Outliers were replaced with the nearest value. The data was normally

distributed for each group as assessed by Shapiro-Wilk test ( $p < .05$ ). The assumption of sphericity was not violated as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). No significant interaction was found. Also, no significant main effects were found.

#### *6.4.2.2.2 EEG Analysis for the Second 100 Trials – Exploring Somatic Markers' EEG Correlates*

A 3X2 repeated measures ANOVA (3 electrode positions and 2 choice selections respectively) was conducted to determine whether there were statistically significant differences in EEG alpha mean voltage amplitude for 400 to 300ms prior to response for F3, FZ and F4 electrodes for advantageous and disadvantageous response choices. Inspection of boxplots revealed outliers in FZ recording for disadvantageous selections – 1 outlier, F3 recording for disadvantageous selections – 2 outliers, in F3 recording advantageous selections – 1 outlier and F4 recording disadvantageous selections – 1 outlier. Outliers were replaced with the nearest value. The data was normally distributed for each group, and Shapiro-Wilk test ( $p < .05$ ), respectively. The assumption of sphericity was not violated for the main effects but was violated for the interaction, as assessed by Mauchly's Test of Sphericity ( $p < 0.02$ ) hence Greenhouse-Geisser correction was applied. No significant interaction was found. Also no main effects were found.

## 6.5 DISCUSSION

The data from this experiment shows that it makes no difference if the emotional images are arranged congruently or incongruently to the risky or safe decks in participants' performance in IGT task. The behavioural data in both experiments

show that participants do not really learn the underlying rules of the task, regardless whether the IAPS images are arranged congruently or incongruently to the monetary awards. The deterioration in performance following the introduction of emotionally potent stimuli can be explained by the interrupting influence that the emotional stimuli might have had in the learning of the task. Both the subjective answers and the analysis of the behavioural data suggest that participants did not learn the task either consciously (as shown by the subjective data) or unconsciously (as shown by the analysis of the responses across the blocks). Prior research shows that emotionally salient stimuli consistently attract attentional resources (see Yiend 2010 for a review), which then interferes with the learning of the task.

The evidence that SM400 reflects Anticipatory Anxiety would have been particularly strong if it reflected Positive and Negative images in the conditions when the IGT task has not been learned. In other words, if the introduction of the positive and negative IAPS images was reflected by the SM400, especially in the absence of evidence that learning had taken place, then there would have been strong support for the idea that SM400 reflected Anticipatory Anxiety.

The most important finding, however, on both experiments in this chapter, is that both show no evidence that the SM400 reflects an Anticipatory Anxiety response. If that were the case, then we would have expected to find SM400 distinguishing between the emotionally Positive and the Negative images. As it was outlined in the introduction, the failure of the SM400 to arise in response to the Negative images relative to the Positive ones support the hypothesis that SM400 is then not related to Anticipatory Anxiety and is more likely to reflect an emotional signal which reflects long-term consequences of the decisions, the Somatic Markers. This hypothesis is further supported by the behavioural data, which shows that in both experiments the

participants do not appear to learn the task and that is followed by the absence of the SM400.

## 6.6 SUMMARY AND FURTHER DIRECTION

Combining the findings from Experiment 2, 3 and 4 (this one), the evidence suggests that the Alpha Power in SM400 is not related to stimulus-reinforcement association learning or anticipatory anxiety response but is instead related to the long-term decision making and the Somatic Markers as hypothesised by Damasio and colleagues.

There has been a long and on-going discussion about the validity of the claims made by the Somatic Marker Hypothesis. (Dunn et al., 2006; Maia & McClelland, 2004; Colombetti, 2008 – also see sections 3.1.7.2, 3.1.7.3 and 4.1). However, in this and the previous two chapters, we have identified an EEG alpha frequency in the central areas of the brain that was able to implicitly reflect the differences between risky and safe choices even in conditions where the participants themselves did not appear to have a conscious appreciation of the rules underlying the situation presented by the IGT paradigm.

Furthermore, possible future alternative were ruled out such as whether the SM400 may actually be related to the stimulus-response association learning, as envisaged by Kringelbach & Rolls (2004), or the possibility that the SM400 is related to the Anticipatory Anxiety. Of course, more research is needed and more independent verifications of the results are necessary before it will be certain that the SM400 Alpha frequency in the frontal areas of the brain reflects that region's capacity to make decisions utilizing biasing emotional signals based on prior learning.

There is one observation, which is particularly important and will underlie the next chapters of the thesis. In experiment I and in the two experiments in this chapter it was observed that the introduction of emotional stimuli has the effect of modulating learning. In the first experiment, it was found that the introduction of the Negative or Positive images did have a predictable effect on participants performance and affected the SA and Information Bias differently whereas in this chapter it was also found that emotional images disrupted learning, even when they were arranged congruently to the risky/safe decks. This suggests that it may be beneficial to be able to gauge participants' emotional state.

An emotional state involves a feeling, which may not be accessible to direct questioning (Nigel, 1974). However, as it will be argued in the next chapter, different emotional states may be related to distinct behavioural and physiological states, which can be used to infer an individual's emotional state. More specifically, there is evidence that different emotional states are associated with distinct variations in the perception of time with the Positive emotions speeding up and Negative emotions slowing down the perception of time passing. Next, the evidence on the relation between the Perception of Time and different emotional states will be assessed and tested. If there is evidence that the correlation holds, then variation on time perception can be used to infer the emotional state of an individual. Furthermore, if this association is supported by experimental data, then an attempt will be made to investigate the EEG correlates of such states.

## **Chapter 7 – The Relationship Between Emotions and Time Perception**

### 7.1 INTRODUCTION

What we see is what we calculate. Aristotle (350 BCE), stated the following on his ‘On Memory and Reminiscence’: “There is no such thing as memory of the present while present, for the present is object only of perception, and the future, of expectation, but the object of memory is the past. All memory, therefore, implies a time elapsed; consequently only those animals which perceive time remember, and the organ whereby they perceive time is also that whereby they remember”.

This chapter will explore the hypothesis whether different degrees of changes in the subjective perception of time, which is an awareness of duration or a hypothesized capacity to use duration information in a task (Matsumoto, 2009), can be fundamentally connected to the operations of specific emotional states. The concept of time as a form of perception will be discussed first, and then several methods and models that have been developed in psychological research to investigate and account for the phenomenon of time perception will be assessed. The focus, however, will be on the possible causal relationship between time perception and emotional states and the plausibility of a causal connection between the effects that emotions have in attention, memory and body processes will be investigated with respect to variations on the perception of time.

### *7.1.1 Perception*

Prior to perception, the sensory nervous system samples and codes information from its environment in several sensory modalities, like heat, pressure, light or chemical composition. However, we do not have knowledge of an analogous sensory system modality that is specialized to register information about time (Ivry & Schlerf 2008), which is why time perception does not have the same logical sensory-to-perception continuity like other modalities of perception do, such as visual or auditory perception. Nonetheless, we all have a feeling or a sense, a sixth sense if it can be called that, of the passing of time, or of the duration of an event. Research has shown however that the sense of time passing or experienced durations are unlike the invariability we expect from the physical time that is measured by a clock. Experienced durations appear to vary from person to person and from situation to situation (Angrilli, Cherubini, Pavese & Manfredini 1997) and the passing of time is sometimes experienced as ‘painfully slow’, such as when we are depressed (Gil & Droit-Volet 2008); ‘fast’ when we feel aroused and happy (Baum, Boxley & Sokolowski 1984; Wittmann & Wassenhove 2009); absent in dreamless sleep or unconscious state and distorted in dreams and highly charged emotional states (Stetson, Fiesta & Eagleman, 2007). It is therefore interesting to investigate under what conditions do these variations in the perception of time occur and whether and how are they related to emotional states. There is no doubt, however that the changes on the perception of time are an interesting phenomenon, which remains vastly understudied, and that developing understanding and tools to measure it may prove beneficial in our attempts to understand the mechanisms by which emotional processes effect cognitive processes of memory and learning.

According to Richard Gregory (1997), perception, more specifically visual perception as an instance of perception, involves much more than just simply processing sensory information. Memory, past experiences, emotions, expectations and so on, all influence perception so that the end result is a much richer product than the sensory data alone allows; the Hollow Face Illusion (Figure 7.1) is a clear illustration of this (Gregory 1970). A contrary position to this view, first advanced by Gibson (1979), argues that the majority of us and for most of the time perception arises as a direct, immediate and reliable representation of the world; indeed, the argument goes, if it was not we could not function. To give a familiar example, if one of our senses is impaired, such as vision, the quality of the perceptual experience is severely limited.



*Figure 7.1: The Einstein Hollow Face Illusion.* Gregory (1970) argued that the hollow face illusion, which consists of seeing a concave mask (left) as a normal convex face (right) provides strong evidence of top down, knowledge driven visual perception.

Most psychologists would agree that both theoretical approaches commonly referred to as top down or concept driven (Gregory 1997) and bottom-up or data driven perspectives (Gibson 1970), are useful for explaining different aspects of the perceptual system (Uttal, 1981). Different perspectives on the same subjects are not uncommon and can be found in most scientific pursuits. Take the brain for example, a cell biologist will have something valid to say about its molecular structure; a neuropsychologist may be concerned with the brain's neuronal activity and their correlation to behavioural and cognitive events, whereas an anthropologist may theorize about the development of the brain as a response to the evolving social structures; each level of analysis seeks to answer sets of different, though related, questions. In this respect, time perception is no different; it can be viewed both as a top down and as a bottom up percept, each view in itself reflecting a different perspective. As it will be argued, this understanding extends to time perception too.

### *7.1.2 Perception of Time Intervals and the Passage of Time*

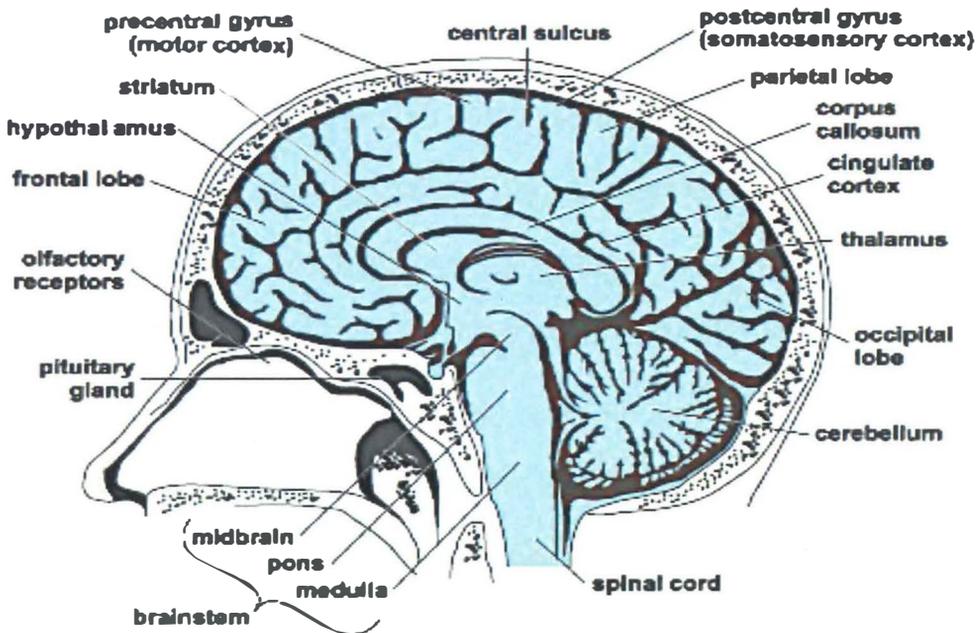
Arguably, the information about the time interval of an event is processed in a top-down manner whereas the sense of the time passing is, a priori, more of a bottom-up percept. The perceived duration of an event, defined here as the interval of time spanning from perceived event onset (beginning) to event offset (ending), logically can only be calculated at event offset. At event offset, when it is possible to calculate the timing interval between onset and offset, all parts of the event, in the Gibson's sense of direct perception, cease to be perceived, meaning that the information about the whole time interval of that event is not perceived directly from the incoming sensory data but rather calculated from the memory trace of the related event (Fortin

& Breton, 1995; Rammsayer, 1994a). On the contrary, the rate of time passing is not connected to event onset-offset like interval timing is; instead, it is there, a priori, on a state of permanent change, with the present time conceived as a fluid boundary between the past and the future (Toda, 1978). Therefore, the perception of time intervals are dependent on memory and consequently, benefit from a top down cognitive processing (Fortin & Breton, 1995) whereas the rate of time passing is sensed, a priori, as the flow or rate of change (Michon, 1985). While the investigation of the rate of time passing is much more resistant to experimental manipulation since it is very difficult to define in precise terms, there have been a large number of studies that have investigated the properties of the perception of various time intervals and their neural correlates.

In a review of time perception studies, Buhusi & Meck (2005) suggest that three separate neural systems for cognitive processing of intervals of time have emerged, each in different time scales: 1) Circadian rhythms, 24 hours light dark cycles, involved in control of sleep and wakefulness, metabolic and reproductive fitness, 2) Interval timing, ranging from second to minutes to hours, involved in decision making and the regulation of the neural systems that control outward, adaptive behaviour such as foraging, and 3) Millisecond timing – involved in motor control, speech generation and recognition; each system depends on distinctive neuronal structures (Figure 7.2).

Circadian Rhythms rely on the neuronal activity in suprachiasmatic nucleus of hypothalamus (Ruby, Burn & Heller, 1999); Interval Timing depends on intact striatum (Matell & Meck, 2004), while it is not affected by damaged suprachiasmatic nucleus of the hypothalamus (SCN) or cerebellum (Buhusi & Meck, 2005) whereas Millisecond Timing depends on cerebellar activity and the Basal Ganglia (Ivry and

Spencer, 2004). The striatum, the globus pallidus (GP), the substantia nigra (SN), and the subthalamic nucleus (STN) together comprise the Basal Ganglia; the latter appears to be important in both Interval and Millisecond timing. The GP consists of two parts: an internal (GPi) and an external (GPe), which also includes the entopeduncular nucleus (EPN). SN is composed of a pars compacta (SNc) and a pars reticulata (SNr). Most commonly information, such as the interval and millisecond timing information from the cerebral cortex, enters the striatum and is forwarded to other parts of the basal ganglia with EPN and SNr forwarding the output to the thalamus and Superior Colliculus (SC) (Bosman, Houweling, Owens, Tanke, Shevchouk, Rahmati, Teunissen, Ju, Gong, Koekkoek & De Zeeuw, 2011). Interval and millisecond timing are on focus here.



*Figure 7.2: Suprachiasmatic Nucleus of Hypothalamus, Striatum and Basal Ganglia.* SCN is responsible for the Circadian Rhythms; Interval Timing is related to the functioning of striatum whereas Millisecond Timing is dependent on cerebellar activity and, perhaps, basal ganglia, which is situated at the base of the forebrain.

### *7.1.3 Current Methods and Models of Measuring Perception of Time.*

Verbal Estimation, Production and Reproduction methods are the three most common methods researchers use to measure the perception of a time interval (Rammsayer, 2002). In Verbal Estimation method, participants are typically required to estimate the time, verbally, in time units like seconds, minutes and so on; in the Production method, an interval is verbally indicated to the participant who thereafter attempts to produce the indicated interval by some operational means, whereas in the Reproduction method, participants attempt to reproduce a previously presented target interval. In addition to reducing some confounding factors associated with the other methods, the Reproduction method is usually the preferred choice as it can be easily adapted for measuring timing in primates as well as other animals.

A relatively new method used to measure time perception is the Temporal Bisection Task. Initially developed by Church & Deluty (1977) to study temporal discrimination in rats (Kopec & Brody 2010), the Temporal Bisection Task requires the comparison of a time interval, Target stimuli, to two other time intervals, Reference stimuli, one longer than the Target and one shorter. Participants are usually familiarized with the Referent durations during training or throughout the experiment (Allan & Gerhardt 2001).

An advantage of Temporal Bisection Task is that several cognitive processes required to perform the task rely in time-dependent processing of information (Kopec & Brody, 2010). At first participants are required to memorize time intervals, the “long” and the “short” one, the Referents. Second the Target interval must be memorized. Third, the Referents and Target durations must be retrieved from memory. Forth a comparison must be made between the two Referents and the Target. Fifth a decision is made as to which Referent the Target is closer to.

A crucially important aspect of this paradigm is that, at a point in time between the Referents, the perception of the Target interval approaches the 0.5, which is when the Target is perceived as being equidistant from both Referents. At the 0.5 point the conditions for making a decision during the comparison of the Referents with the Target are equal for both Referents. It is at this sensitive point, as it will be further argued below (section 7.1.5), that we ask the question, does the manipulation of the emotional Valence of the Target interval has discernable effects on the perception of its duration?

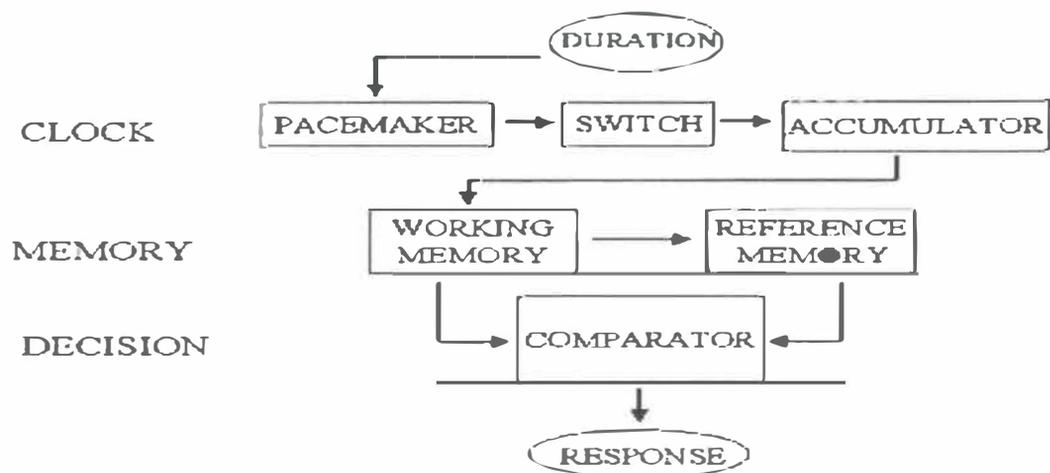
An additional advantage of Temporal Bisection Task is that the cognitive processes required to perform it closely correspond to the components of the Pacemaker-Accumulator model (see next section), which is the most validated model of time perception, although not universally accepted (Staddon & Higa, 1999).

#### *7.1.3.1 The Pacemaker-Accumulator Model*

While a number of competing theoretical models that account for Interval Timing have been suggested: neural oscillators (Miall, 1989; Church & Broadbent, 1990), sustained neural activation (Machens, Romo, & Brody, 2005; Grossberg & Schmajuk, 1989), network dynamics (Dragoi, Staddon, Palmer & Buhusi, 2003), switching among behavioral states (Killeen & Fetterman, 1988), the pacemaker-accumulator model (Treisman 1963) is possibly the most validated information processing model of time perception (Buhusi & Meck, 2005). It is based on the conception of an internal clock, which has an oscillator-like pacemaker that generates regular pulses (Figure 7.3) and appears to be underlined by the Dopamine systems (Matell & Meck, 2004), and an accumulator that registers those pulses. Pulses that are registered in the

accumulator are stored in reference memory, which can be described as a subtype of semantic memory that stores learned durations. It is hypothesized that participants responses during timing tests depend on the comparison between immediate subjective experiences of a duration, which is represented as pulses stored in the accumulator (working memory) against a range of previously registered durations in reference memory (Gibbon, Church, & Meck, 1984).

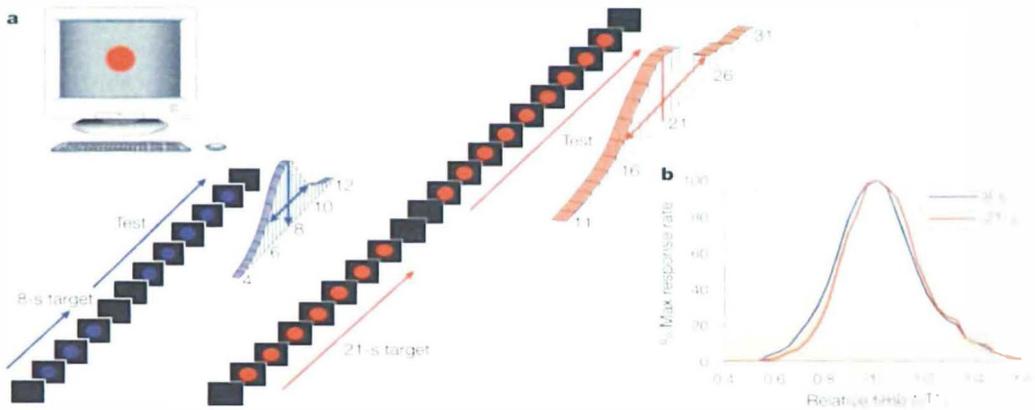
An important advantage of this model is that it supports a clear theoretical distinction between the clock and processes of memory, which enables researchers to test for dissociations between the two in terms of brain and behavioral data. Another advantage is that, though relatively simple, it has been powerful in accounting for the evidence from a large number of behavioral and neuroscience studies (Buhusi & Meck, 2005).



*Figure 7.3: The Pacemaker-Accumulator Model.* The Pacemaker-Accumulator model showing an accumulator receiving pulses from a dopamine pacemaker, interval times are then transmitted to working memory and coded into the reference memory. During testing, stored time intervals reference memory are compared against those in working memory; the latter are passed on directly from the Accumulator during a timing task.

For example, it has been found that drugs that attenuated activity of the dopamine system, modulate the clock so that the subjective clock speed will decelerate in proportion to increased drug affinity to D2 receptor antagonist (Matell & Meck 2004; Buhusi & Meck, 2005) whilst, on the other hand, dopamine (DA) agonists shift the responses leftward in a scalar scale, suggesting an accelerated internal clock speed. Whereas drugs that affect the cholinergic systems appear to have an effect on the next stage of the Pacemaker-Accumulator model, the memory part (Meck 1996); The effects of pharmacologically increasing or decreasing levels of Acetylcholine (Ach) in the brain (i.e. using anticholinesterases physostigmine and neostigmine to increase Ach levels or cholinergic receptor blockers atropine and methylatropine to decrease Ach effects) suggest that Ach levels are proportional to the absolute error of a Temporal Memory Translation Constant (Meck & Church 1987; Buhusi & Meck 2005). Temporal Memory Translation Constant is a multiplicative translation variable within the scalar expectancy theory, which reflects the scalar transformations of temporal information from the internal clock to the temporal memory (see next section).

Another common finding has been that responses tend to become less accurate and more varied in proportion to the magnitude of the length of the judged durations (Buhusi & Meck, 2005) and this property of time estimation is expressed by the scalar property, which is a variation of Weber's law. Scalar property denotes the covariance between the mean and the standard deviation (Figure 7.4).



*Figure 7.4: The Scalar Property of Time Perception.* Taken from Buhsu & Meck (2005). a) Shows two typical reproduction studies, one using 8 seconds duration, the other 21 seconds. The width of the normal distribution increases proportionally with the length of the duration. b) The Scalar property is evident when the responses are scaled and superimposed.

#### 7.1.4.2 The Scalar Expectancy Theory (SET)

The scalar property was proposed by John Gibbon (1977) within the Scalar Expectancy Theory (SET). SET is supported by a range of behavioural studies with animals which investigate the timing of the occurrence of a conditioned response (CR) in reference to the appearance of a conditioned stimulus (CS) and is based on the assumptions made by the pacemaker-accumulator model (see figure 7.3 above), namely, a timing mechanism, a memory mechanism, sources of variability in decision variables, i.e. length of interval, and a comparison mechanism (Gallistel & Gibbon 2000). The signal generated by the timing mechanism from onset to offset, according to Gallistel & Gibbon, is continuously proportional to the elapsed duration and represents the measure of the interval which is written to the memory through a multiplicative translation variable, denoted with  $k^*$ , whose value is close to but not 1. Thus, the duration stored in memory is determined by the multiplication of the magnitude of the interval with the  $k^*$ , expressed by the equation:

$$1) t^* = k^*tT$$

where  $t^*$  is the remembered duration and  $tT$  is the magnitude of timed interval at offset. When a current time interval, denoted by Gallistel and Gibbon as  $te$ , is compared with one previously recorded in memory,  $t^*$ , the comparison takes the form of the ratio  $te/t^*$ , which is called the decision variable. In reference to CS, CR occurs when a threshold,  $B$ , is exceeded. In other words when:

$$2) te/t^* > B.$$

A further feature of this model is the Expectancy to Reinforcement defined as the total amount of expectancy that a single reinforcer will support, spread back uniformly over the estimated time to reinforcement and denoted by the letter  $H$ ; at interval time zero,  $t = 0$ , the value of  $H$  is  $H/x$ , where  $x$  is the estimated time to reinforcement and is denoted by the symbol  $h(o)$  which equals  $H/x$ . Therefore, from onset onwards,  $t > 0$ , as the time to reinforcement decreases, the expectancy function,  $h(t)$ , mathematically expressed as:

$$3) h(t) = H/x - t,$$

In which case, the expectancy ratio,  $r(t)$ , which is expressed as :

$$4) r(t) \equiv h(t)/h(o) = 1/1-(t/x) > b. - \text{where } b \text{ is the threshold response level.}$$

increases hyperbolically (Figure 7.5).

Within this model, Gibbon (1977) reports that when a positive reinforcement schedule is used, the estimated time to reinforcement is inversely related with the expectancy of reinforcement. Passing the threshold level,  $b$ , determines when a response occurs. The threshold is passed when the ratio of local,  $h(t)$ , with overall,  $h(o)$ , exceeds threshold value.

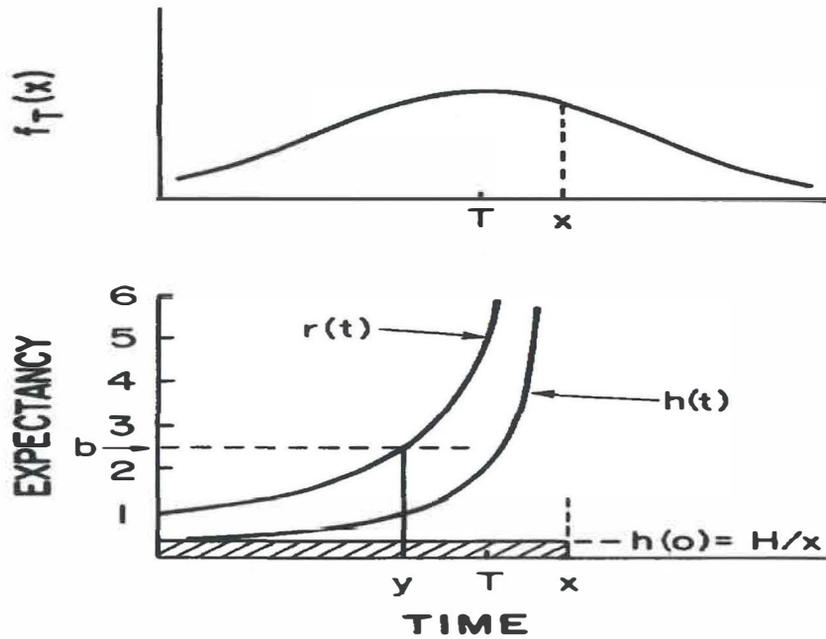


Figure 7.5: Gibbon's Model of the Relationship Between Time and Learning. Taken from Gibbon (1977) as is. Estimates of fixed-interval time,  $T$ , (top panel) with a sample,  $x$ , indicated. Expectancies of reinforcement based upon that value are shown in the lower panel. The expectancy function  $h(t)$ , and the expectancy ratio  $r(t)$ , are hyperbolic in  $t$  and the point at which the expectancy ratio crosses the threshold,  $b$ , is indicated as  $y$ .

Looking carefully at this model there is an interesting implication. If the value of  $H$  decreases due to either environmental or internal factors, then the threshold,  $b$ , is passed slower and vice versa if the  $H$  value increases. We will come back to this model later, but it is worth noting at this point a plausible hypothesis that the value of  $H$ , which represents the value of the stimuli (or in simpler words the emotional intensity that a reinforcement stimuli can elicit), may increase or decrease as a function of overall affective intensity. If so, we can speculate that the findings from some of the studies referenced above, (Matell & Meck 2004; Buhusi & Meck, 2005), may be translated as effects that dopamine has on the computed initial value of  $H$ . It may be that when stimuli used in the time perception task is judged in a context of a positive emotional valence then the initial value of  $H$  is smaller (for example, a well

fed rodent - positive emotional context - will be less motivated to respond to food stimulus - the value of H would be lower - than a starved one) which suggest that, in these conditions, participants will tend to respond slower, whereas when the stimuli is judged within a negative emotional context, than the initial value of H is larger leading towards the opposite, people respond faster; in other words time perception is speeding up or slowing down respectively, according to the affective intensity. Evidence to support this hypothesis will be discussed below.

#### *7.1.5 Why Time Perception?*

Knowing about variations in individual time perception may be useful for two reasons, namely, the implications when the normal functioning of the timing system is disrupted may be important, and secondly, it has been recently suggested that the normal variations in the brain's timing system may provide a reliable and valid way to gauge the involvement of emotions as well as the mechanisms by which they affect behaviour (Droit-Volet & Gil, 2009). To give an example, the ability to correctly estimate timing of events has a an effect in our ability to mobilise resourceive, cognitive and others, so that we are prepared for the anticipated events (Janssen & Shadlen, 2005).

While some degree of variance in time perception, as shown by the scalar property, must be normal and, presumably, accommodated for by other systems of the brain that depend on timing information, if time perception is at relatively major variance with the absolute time (clock time), it might lead to adverse effects on a wide range of important cognitive functions. Major shifts in the perceptual time may result in the impairment of the ability to make correct associations between bits of information, which, consequently, would reduce the odds of creating a correctly

integrated image of an event or situation; the latter is usually referred to as Situation Awareness (SA). Having a coherently integrated picture or model of a situation (or having SA) requires an immensely complex temporal organization of sensory, perceptual and memory information; therefore, temporal binding of sensory (bottom up) and memory (top down) data is crucial for a rationally unified conscious experience that closely approximates behavioural goals. Neuroscientist Antonio Damasio expresses this most clearly in the following statement (Damasio, 1994, pg. 95-96) *“if the brains integrate processes into meaningful combinations by means of time, this is a sensible and economical solution but not one without risks and problems. The main risk is mistiming. Any malfunction of the timing mechanism would be likely to create spurious integration or disintegration”*. Moreover, *“The fundamental problem created by time binding has to do with the requirement for maintaining focused activity at different sites for as long as necessary for meaningful combinations to take place. In other words, time binding requires powerful and effective mechanisms of attention and working memory”*.

The problem of timing, or mistiming, can be elucidated from the perspective of the classical and operant conditioning. A note aside, from the perspective of time perception, classical and operant conditionings are the same because, after all, two basic aspects that determine conditioned response (CR), rate and timing of the presentation of conditioned stimulus (CS) relative to unconditioned stimulus (US), are basically synonymous (Gallistel & Gibbon, 2000).

Two widely used behaviorist research paradigms, forward conditioning, within which are encompassed delayed and trace conditioning, and temporal conditioning are particularly well suited to highlight the problem of mistiming. In delayed conditioning, the CS remains present until the US is presented whereas in

trace conditioning, the CS is first presented, then some time elapses, then the US is presented; in temporal conditioning, the US is presented at regularly timed intervals and the acquisition of CR depends upon correct perception of the timing of the interval between US presentations, which in this case serve as the CS. The obvious aspect that permeates all of these and other similar conditioning procedures is the processing of elapsed duration between CS and US; in other words, the timing of the interval between the two.

There is evidence that the time interval between CS and US affects the timing between CS and Conditioned Response (CR) so that the larger the time interval between CS and US the larger the time interval between CS and CR (Gallistel & Gibbon, 2000). Gallistel and Gibbon argue that knowledge about the inter-stimulus interval, instead of being adjunctive to associative learning, represents, instead, the core of classical and instrumental learning. If that is true, then we can conclude that if learned time intervals are distorted under conditions of high emotional arousal, negative or positive, the formation of new associations or the retrieval of already learned ones is affected, resulting in an overall spurious integration. This conclusion is backed by a wealth of research that has found many detrimental effects that high levels of emotional arousal can have in a wide range of higher cognitive functions, such memory, attention and, as will be further explored below, time perception.

#### *7.1.6 Emotions and Time Perception*

There is both anecdotal and experimental evidence which supports the proposition that cognitive effects of emotions on attentional and memory processes may also be reflected in the perception of time. This is how one of the witnesses of the terrorist incident in Mumbai, India, described his experience while under attack, "It was the

longest 10-15 minutes of my life," (BBC, 2008). Carson (1982) reports other similar situations where, for example, the pilots who were forced to eject from their aircraft in an emergency experienced a slowing down of their environment within their conscious perceptual field, much like a slow motion movie clip. Similarly, many other researchers have reported that the perception of danger consistently leads to a dilation of the perceived time intervals (Carson 1982, 1983; Hancock & Weaver 2005). The conscious experience of time slowing down appears to be caused by real or perceived extreme degrees of danger – we can safely assume that if a situation is perceived as dangerous to the self by an individual, his or her emotional reflection of such situation will tend to be characterized by high arousal and negative valence. There is no reason why the conscious perception of the time slowing down does not have an unconscious equivalent that occurs in situations that involve high but not extreme degrees of negative emotions.

According to Eagleman (2008), an increased temporal resolution of recorded events is responsible for the phenomenon of perceived time interval dilation. Eagleman suggests that high arousal, such as that caused by a highly threatening event, causes the brain to increase the temporal frequency of events recorded within the same duration of physical time – in other words, the neural circuits of the brain which are in a state of high arousal are able to process information in greater detail which, according to Eagleman, is the reason for the dilation of the perceived time interval. Other researchers too have favored the hypothesis that the brain estimates time based on the frequency of recorded sensory information (Khoshnoodi, Motiei-Langroudi, Omrani, Diamond & Abbassian (2008); Treisman & Brogan, 1992; Treisman, Faulkner, Naish & Brogan, 1990). For example, Khoshnoodi and his colleagues exposed participants to different durations of vibro-tactile stimuli. They

reported a correlation between increased stimulus frequency and overestimated time intervals; the overestimated time intervals were independent of gap durations between successive stimulus presentations and context. Furthermore, Khoshnoodi et al., (2008) reported that the effect was correlated with the frequency rather than the rate of presentation. Similarly, Treisman & Brogan (1992) reported that increasing the frequency (from 2.5 to 17.5 Hz) of a visual flicker induced, reliably, increased (or decreased if the frequency was reversed from 17.5 to 2.5 hz) time estimates. In real life, it makes sense that the brain increases its sensory powers to negotiate with what it perceives as dangers. However, it appears, that this increase when pushed to extremes, such as by extreme fear, exposes the cognitive systems to levels of sensory information that it is not capable to process, a kind of emotionally induced cognitive overload, and it suggests that during those moment, an individual would then have to rely on the activity of its older phylogenetic parts, subcortical areas, to deal with danger, which can be inadequate and perhaps maladaptive for some of the different kinds of problems that we face in the modern age (LeDoux, 2002).

For instance, many studies have found that an emotional stimulus, aside from time perception, affects memory in a way that it is improved for central details at the cost of overall and peripheral information; not much of a hindrance if the problem after you is in the shape of a hungry saber-toothed cat; in fact, increased acuity for central details would help the detection and the subsequent fleeing from such dangers which explains why this behavioural response was evolutionary adaptive in the first place.

For example, a study carried out by Mather et al., (2006) looked at emotional arousal effects in feature binding in memory. On a series of successive trials, participants were presented with four pictures of high, medium and low emotional

arousal and were asked to monitor and remember the locations of the pictures on the screen. They found that memory for picture location, which can be considered as peripheral information, worsened as emotional arousal increased and that participants with higher depression scores had the worst memory for the location of the negative pictures. These differences were also associated with differential brain activity too. Functional magnetic resonance imaging (fMRI) recording showed that relative to low arousals, high arousals showed increased activity in the fusiform gyrus, middle temporal gyrus/middle occipital gyrus, lingual gyrus and less activity in superior precentral gyrus and the precentral superior temporal intersect. Mather et al., (2006) concluded that high arousal and negative valence stimuli, attracts attention in such a way that the normal functioning of working memory is disrupted, leading to the impaired binding of memory elements. Similarly, Hulse & Memon (2006, 2007) found that, in emotional situations, people form enriched memories but these memories, however, are usually centered around the perceived source of danger, possibly because of the involvement of amygdala (Phelps & LeDoux 2005), which causes the attentional tunneling effect (attention narrows down to the elements that are perceived as most threatening; a survival feature).

Kohn (1954) also recognised this when he wrote: “Under conditions of stress...the perceptual field is constricted or narrowed, and the scope or span of behaviour tends to be restricted to those elements which contribute most to the direction of behaviour, or to those elements which appear to be the most threatening.” (p. 290). Kohn demonstrated this in an experiment where participants were required to comprehend and recall a story under conditions of high, low and no threat (threat was represented by the possibility of receiving an electric shock). He found that, under the threat condition, memory performance was impaired over all, but it was

selective for main features. However, Friedland, Keinan & Regev (1992) showed that, in soldier training, the detrimental effects of emotions on memory could be attenuated if stressors that are likely to be encountered are incorporated into their training.

Similar findings were also reported by, Callaway (1959) and Callaway & Dembo, (1958) for anxiety and its relation to the perception of size. Callaway & Dembo, using a between subjects paradigm, asked one group to inhale amyl nitrite which causes decreased blood pressure, followed by an increased heart rate, flushed face and neck, dizziness, and headache. Another group were asked to put their feet in cold water causing distress. They found that under these conditions, participants tended to overestimate the size of the objects relative to controls, in a visual perception task. Estimating the size of an object requires processing of contextual cues, therefore, distorted perceptions were attributed to the tendency to focus on the main elements of a visual scene while ignoring peripheral information.

The cost of this attentional tunneling is poor overall memory formation for other possibly relevant situational elements (Wessel & Merckelbach, 1998) whereas the benefit is that if peripheral information is not needed, then filtering it out helps improve performance. However, emotionally induced bias in the cognitive processing, as in the attentional narrowing effect described above, has detrimental effects on the overall mental representation of a situation. The accuracy of the latter is often cited as an important aspect of SA (Endsley, 1995) and therefore, it can be concluded, that the attentional narrowing has detrimental effects on the formation of SA. Whereas to describe the effects of emotionally induced attentional narrowing in terms of QASA, within which SA is described as different in different situations, then SA in such conditions is characterized by Focused Situation Awareness (FSA) which is typical,

and may indeed be advantageous, in highly dangerous situations (see Chapter 1 for further discussion on this theme).

Wittmann & Wassenhove (2009) write about emotions that: “Insofar as the experience of time is tied to the mental status of the beholder, it reflects one’s cognitive state and emotional well-being. Regarding the sense of time in relation to seconds, minutes and hours, our subjective well-being strongly influences how time is being experienced: time flies during pleasant activities but drags during periods of mental distress“. Extending from the above quote, it is logical to suggest that measures of the variations of an individual’s time perception may be utilised as indicators of specific emotional states. Thus, it will be argued that, affective intensity and the length of a time interval have a similar effect on estimations of time perception; an increased intensity of an emotional experience, as measured by arousal and valence, produces proportionally increased variability in the responses, with the addition that, the emotional valence conditions the direction of the variability. In other words, as the affective intensity increases, the disparity between clock and experienced time also increases, and the direction of that disparity as reflected by an under or over-estimation of time that is concurrent with the valence in a way that a positive valence will tend to lead to relative under-estimations and negative valence with relative over-estimations. Research in this topic is relatively scarce; however, Angrilli et al (1997) have reported just such results using a selection of photos from International Affective Picture System (IAPS), which is, arguably, the most standardised set of emotional stimuli available (Lang et al., 2005). Angrilli and colleagues reported that at 2, 4 and 6 seconds presentations, negatively valenced stimuli produced a significant contraction of time perception under conditions of low

arousal and a significant expansion under conditions of high arousal; the opposite was found to be true for emotionally positive stimuli.

At this point, we can speculate that if the measures of time perception for a given individual indicate that his or her perceptual time is relatively slowing, then that would indicate a move towards a negative emotional state and towards a positive state if the experienced time is speeded up. Therefore, we can hypothesize that the knowledge of the degrees of changes in an individual's time perception could enable us to estimate the intensity and valence of a person's emotional state. Having such knowledge may enable us to estimate the kind of SA a person is likely to have.

For example, if we can infer that participants relative to a neutral state, are in a negative emotional state, we may be able to infer from that that they are likely to have a type of SA that is focused, (FSA), conversely, if they are in a relatively positive emotional state, then we may infer that the type of SA they are likely to have is distributed, (DSA).

## 7.2 EXPERIMENT 6: IS NEGATIVE EMOTIONAL AROUSAL RELATED TO A DILATION OF TIME PERCEPTION AND A POSITIVE EMOTIONAL AROUSAL TO A CONTRACTION OF TIME PERCEPTION?

The main aim of this experiment is to study the influence of stimulus-induced emotional arousal and affective valence on the experience of time while viewing standardized (images selected from the International Affective Picture System) photographic slides rated for valence and arousal. The prediction is that negative emotional stimuli will be over-estimated and positive one under-estimated relative to neutral stimuli. Also, an associated measure, which gauges the participants' ability to recall specific details in the images, is expected to show that negative emotional

images reduce memory recall performance and the positive images improve it relative to neutral images.

The emotional responses induced by the standardized slides develops within about 6 sec and then is extinguished (Greenwald, Cook & Lang, 1989; Lang, Greenwald, Bradley & Hamm, 1993), thus it was decided to choose a 6-sec Target interval presentation.

### 7.2.1 Method

#### 7.2.1.1 Participants

Fifty-one participants were randomly selected (opportunity sampling) mainly from students of the first, second and third year of the psychology course at the University of Gloucestershire (mean age = 28.45, SD = 7.22, 16 female, 47 right handed). Participants were further split into three groups according the stimuli to which they were exposed, Positive, Negative or Neutral valence (see below for further details). Below is the table with Age, Handedness and Gender information organised by groups (Table 7.1).

	Demographics			
	Age (SD)	Handedness (Right)	Gender (Female)	
Groups				
	Positive	27.00 (6.52)	14	4
	Negative	31.06 (8.04)	17	6
	Neutral	27.29 (6.71)	16	8

Table 7.1: Demographics Organised by Groups.

### 7.2.1.2 Materials

#### Spielberg State Anxiety Inventory

The same questionnaire as used in experiment 1.

#### International Affective Picture System (IAPS)

Sixty colored pictures were selected from the IAPS (Center for the Study of Emotion and Attention, 1999) consisting of 20 Positive, 20 Neutral, and 20 Negative pictures, based on IAPS Valence and Arousal ratings. Positive pictures included erotic couples and happy families; Neutral pictures included neutral faces and household objects; Negative pictures included mutilated bodies and scenes of attack and threat. Positive and Negative pictures were selected to be the most arousing exemplars in each respective subcategory. Normative ratings of valence (which varies across the Negative and Positive axis with Neutral being in the middle) and arousal (which varies across High and Low axes) for pictures in these categories differed (Table 7.2 below):

- *Emotional calibration set (n = 6): 5760, 5780, 5750, 7492, 5825, 5725.*
- *Positive Set (n = 20): 2050, 2070, 2080, 2160, 2165, 2170, 2311, 2340, 2341, 2360, 4650, 4651, 4652, 4658, 4659, 4660, 4664, 4670, 4680, 4690.*
- *Neutral Set (n = 20): 2190, 2200, 2210, 2230, 2381, 2440, 2480, 2570, 2850, 7002, 7009, 7010, 7020, 7030, 7040, 7080, 7175, 7233, 7235, 9070.*

- *Negative Set (n = 20): 1050, 1120, 1201, 1300, 1930, 3000, 3010, 3051, 3060, 3071, 3080, 3102, 3110, 3130, 3530, 6260, 6350, 6510, 6540, 9405.*

<b>Normative rating of Arousal and valence for the four sets of chosen photos</b>				
	<i>Calibration (n = 6)</i>	<i>Positive (n = 20)</i>	<i>Neutral (n = 20)</i>	<i>Negative (n = 20)</i>
<i>Arousal (mean)</i>	4.01	5.7	2.6	6.4
<i>Valence (mean)</i>	7.45	7.4	4.9	2.6

*Table 7.2: Normative Ratings for the IAPS Images.* Normative ratings are given for all the IAPS images sets selected, Calibration set plus Positive, Neutral and Negative sets.

### Stimulus Presentation Computer

Stimulus presentation was controlled by e-prime version 2.0 (PST, Inc.), running on a Dell PC, using Microsoft Windows XP with Service Pack 2.

Each image was presented on a 0.48m diagonal, 4:3 aspect ratios and a computer screen with a frame refresh rate of 60 Hz. The screen was placed 1.5 m in front of the viewer, resulting in a picture presentation with a visual angle of 14.7 degrees of visual angle horizontally and 11 degrees vertically.

#### *7.2.1.3 Design*

Initially all participants completed the SAI questionnaire which was used to evaluate the participants' baseline anxiety levels and also to divide them into three groups of High, Medium and Low Anxiety. SAI questionnaire was also administered at the end of the experiment to evaluate the effect that the emotional images had in the participants' anxiety levels. It is expected that participants in the Negative group will show increased and those in the Positive group decreased anxiety levels relative to participants in the Neutral group.

After administration of the first SAI, all participants were exposed to the Emotional Calibration set (see above) which were relatively pleasant images selected from the IAPS. This set was used to bring the emotional arousal of all participants in all groups to a similar baseline level prior to starting the main task. After which, participants were trained to distinguish between the Long and Short Referent durations.

Next, the main part of this study utilized a between subjects design with one independent variable (Valence) with three levels, Positive, Negative and Neutral. There were two main DVs, the Bisection scores that measure the participants duration experience of the Target stimuli relative to the durations of the Referent stimuli, and a time Estimation score which measures the perceived duration of the Target on a Likert scale of 1 to 6, 1 being “very short” and 6 being “very long”. It is predicted that more emotionally Positive images will be perceived as Short and more emotionally Negative images will be perceived as Long relative to the Neutral images.

There were four further DVs, two of which measured participants’ Arousal and Valence associated with each image. This score was expected to approximate the original scores given in the IAPS set and, along with the anxiety scores (SAI), were used to assess the effects that the images in the Positive, Negative and Neutral groups had on participants.

The third DV measured participants SA scores. They were asked to respond true or false on questions, which stated whether there was (or was not) some particular element in the emotional image presented in each trial. Since this was a peripheral to the main task, it was expected that participants in the Negative group would perform significantly worse, and participants in the Positive group significantly better than participants in the Neutral group.

And the fourth DV measured participants' Confidence scores on the answers. This was an exploratory DV, which was meant to assess whether different emotional states are reflected in different levels of confidence.

#### *7.2.1.3.1 Procedure*

##### Time Judgment Method

Participants were verbally informed at the beginning of the experimental session that their main task would involve time estimation. Two different time estimation methods were used, Bisection and time Estimation. In the first method participants were required to decide whether the Target duration, was closer to either of two Referent durations; one 3 seconds shorter than the target stimuli the other 3 seconds longer. The other measure of perceived duration asked participants to decide on a 6 point scale the duration of the target stimuli: 1 representing the shorter, 3 second duration up to 6 which represented the longer, 9 second duration.

The main task had 20 trials. To assess the Perception of Time Intervals, Arousal, Valence, Confidence and SA levels associated with each image presented in each trial, six questions were asked at the end of each series of image presentations assessing the perceived durations of the Target images relative to Referents, a direct Estimate of the durations, Confidence in their judgments, and Valence and Arousal Ratings for each IAPS image. Also, at the end of each trial a question was asked about a particular detail of the emotionally Valenced image; the last question was used to assess participants' SA.

##### Outline of the experimental steps

*Step 1 - Assigning participants according to their initial emotional arousal scores*

After giving informed consent, the participant was led into a dimly lit room and asked to sit in a reclining chair. The experiment was entirely presented on the computer screen and the experimenter was absent throughout the duration of the experiment. Participants were asked to follow instruction from the computer screen.

Participants were asked to complete a State Anxiety Inventory (SAI) (Spielberger, 1989). The latter score was used to separate participants into three groups:

- 1) High Arousal - had a summed score over 43
- 2) Neutral - had a summed score between and including 33 to 43
- 3) Low Arousal - had a summed score under 33

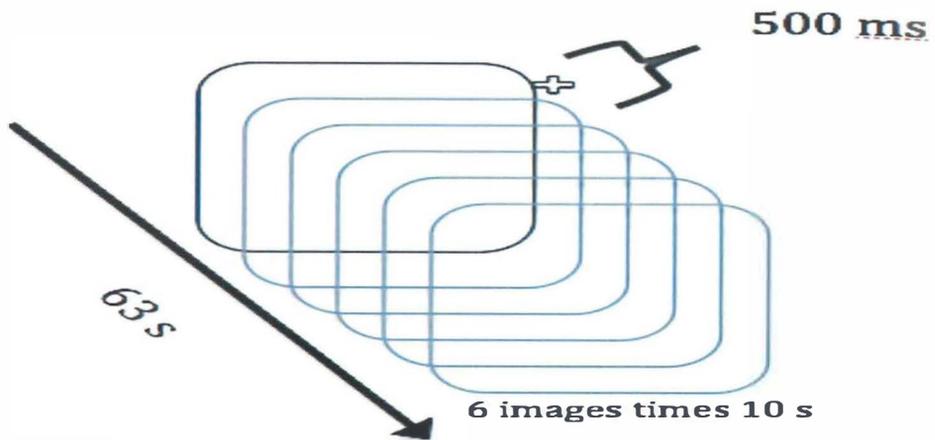
The cut-off points were determined by the means reported in STAI manual for university students. The mean of State anxiety scores for university/college students are reported to be 36.47, SD = 10.02 for males and 38.76, SD = 11.95 for females. The overall mean is therefore 37.62 which was rounded up to 38. The low and high cut off points for the Neutral group were set at the range of 1 SD around the mean.

A computer program designed for this experiment using *E-Prime*, searched for the above values and randomly assigned high and low arousal groups in equal probability to one of two conditions: Positive, Group 1 (G1) or Negative, Group 3 (G3) whereas the Neutrals were the control group, Group 2 (G2) and were automatically assigned to the Neutral condition as follows:

$32 > G1 > 43$  and Group 3 (G3):  $32 > G3 > 43$  whereas G2:  $33 \Rightarrow G2 \leq 42$ .

This was done in order to have an overall equal anxiety scores in the Negative and Positive groups.

After this, all participants passively watched 6 images from the Emotional Calibration set which were presented for 10 seconds each, on the same order as given in the set. A fixation cross in the middle of the screen was presented for 500 ms between each image (figure 7.6).



*Figure 7.6: Temporal Arrangement of the Emotional Calibration Set.* Participants are presented with 6 images, which stayed on screen for 10s each, presented at 500ms intervals. This presentation was the same across all groups and it was used as way of calibrating the participant's emotional arousal to the same level across all groups.

#### *Step 2 – Training participants to distinguish between the Referents*

Next instructions were given to participants to observe an image 6 times (Image number 7006 from IAPS set. Normative Valence and Arousal ratings were 4.61 and 2.08 for male and 5.09 and 2.58 for female respectively. Over all Valence and Arousal ratings were 4.88 and 2.33 respectively) and distinguish between two randomly presented durations, one longer, termed as LongD (9000ms) one shorter, termed as ShortD (3000ms). After each image presentation, feedback was presented on screen for 1000ms informing the participant whether it was a LongD or ShortD.

Next participants were asked to actively distinguish whether the same, randomly presented durations of 400 and 1600ms were LongD or ShortD. Feedback was given after each attempt. At the end of this step, participants were asked to continue only if they felt confident they could distinguish between these two durations comfortably.

*Step 3 – Main task, assessing the effects of emotions in the perception of time*

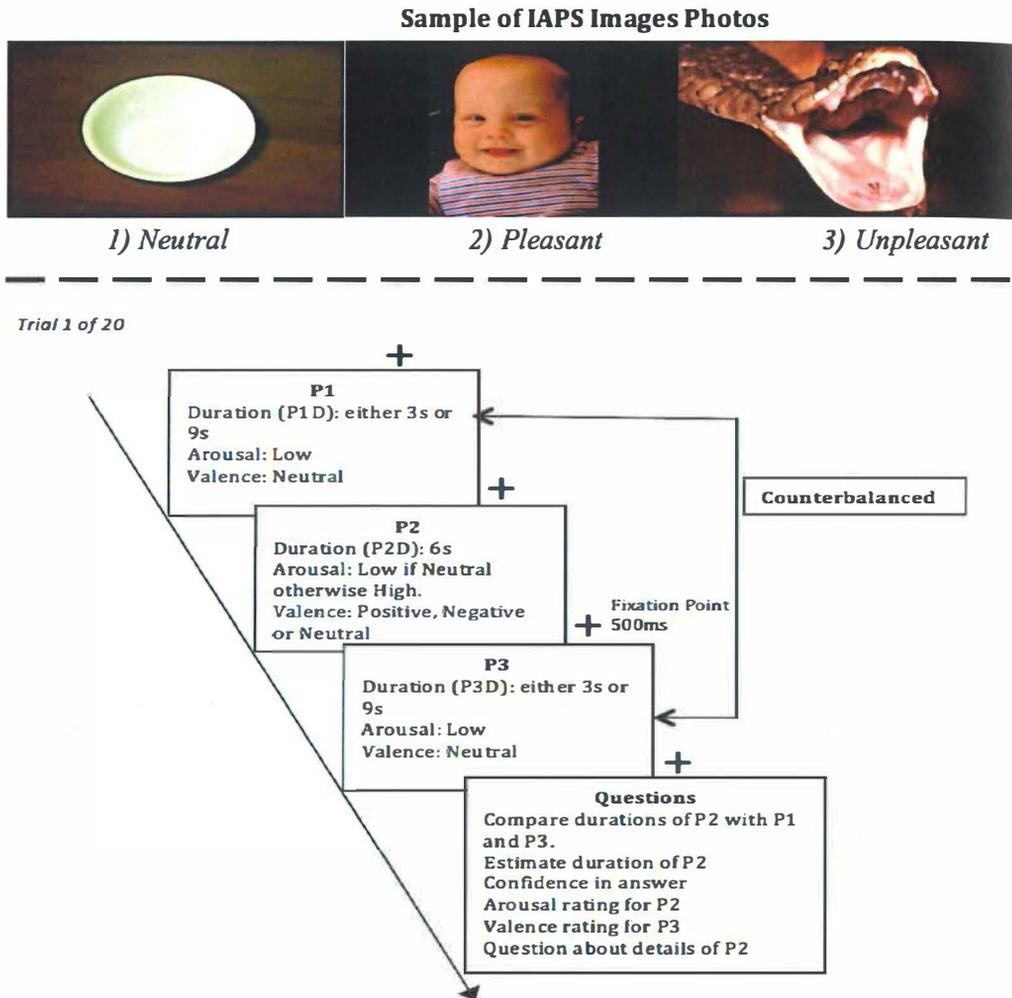
The next step of the study assessed the effects of induced emotional arousal on time perception. This phase involved the random-order presentation of 60 photos, of which 40 were the same photo of a globe (IAPS picture nr. 706, figure 7.7, left) that has a neutral emotional valence and was used to present the Referent durations, and 20 other photos that are the Target duration and which contained the Positive, Negative and Neutral emotional valences. According to the scores from the STAI (as explained above) participants were exposed to either 1) Neutral, 2) Positive or 3) Negative images (see sample images below, figure 7.7).

In the main session (figure 7.7), each participant was asked to complete 20 trials. In each of the 20 trials, participants were presented with three successive images (P1, P2 and P3 respectively). P1 and P3 (the Referent durations) were the same throughout the trials, (IAPS image nr. 706, figure 7.6 left) and groups, and had a neutral Emotional Valence. In each trial, P1 and P3 durations were counterbalanced and randomized to have one of two durations: 3 seconds or 9 seconds.

P2 (which was the Target stimuli) was, according to the group, Neutral, Positive or Negative and was exactly 6 seconds in duration.

In each trial participants were asked to judge whether P2D (D = duration), the duration of the target stimulus, was closer to the longer or shorter duration

(represented by P1D or P3D). The P1D and P3D were counterbalanced across trials and the photo used for these trials remained the same across trials and groups.



*Figure 7.7: The Main Experiment Structure.* The main experimental structure (below). Above is a sample of the images used in each category, Neutral, Positive and Negative from left to right.

After each trial of image presentations, participants were asked a total of 6 questions:

- 1) *Bisection question:* Asks participants to make a judgment as to whether P2D (the target) was closer to the longer or shorter durations, represented by P1D and P3D.

- 2) *Estimation question: Asks participants to indicate on a 6 point Likert scale how close P2D was to the Short or to the Long Duration, where 1 = Extremely close to the Short Duration and 6 = Extremely close to the Long Duration.*
- 3) *Confidence question: Asks participants to indicate their confidence in their answers on a 4 point scale (1 - not at all confident, 4 - very sure).*
- 4) *Arousal Estimation question: Asks participants to indicate on a 9-point Likert scale how strong or weakly mentally arousing was the photo (1 – Weakly Arousing, 9 Strongly Arousing).*
- 5) *Valence Estimation question: Asks participants to indicate, on a 9-point Likert scale, how strong was the emotion evoked by the photo (1 – Very Weak, to 9 – Very Strong).*
- 6) *Situational Awareness question: States the presence or absence of some detail on P2. Participants answered by selecting either True or False on computer screen.*

#### *Step 4 – Control Questions and Debriefing*

Participants were questioned by the experimenter whether they had understood all the on-screen instructions correctly. All participants were fully debriefed.

#### *7.2.2 Results*

The data will analysis will be arranged into four categories. The first Category encompasses analyses of the Anxiety, Arousal and Valence scores, which together indicate the extent of the effects that the emotional stimuli has had on participants. Next, the Confidence scores will be analysed to see whether there are differences in

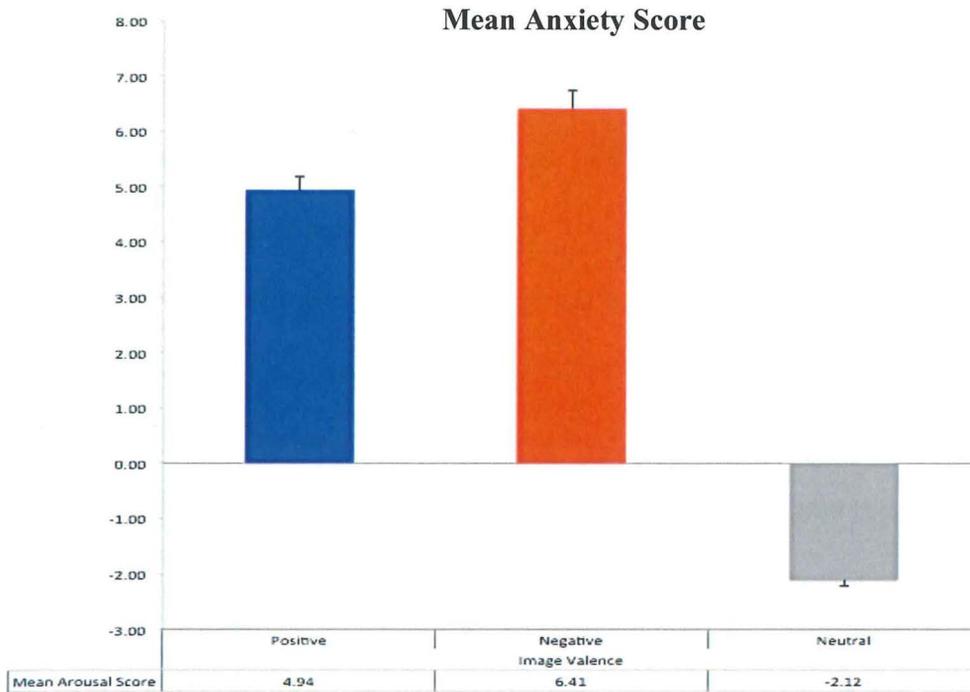
confidence between different groups. The third category will be the SA scores. Bisection and Estimation scores are in the fourth category which directly tests the relationship between different emotions and the perception of time. In the fourth category a correlation will also be run between the Estimation scores and Valence scores to test for the extent and direction of correlation between emotions and time perception.

#### *7.2.2.1 Anxiety Levels Control Results*

##### Category 1 – Effects of Emotional Stimuli on Participants

The responses of participants on the SAI questionnaire were calculated by first adding the scores for each of the participants separately at the beginning of the experiment and at the end of the experiment then subtracting the Anxiety score at the beginning from the score at the end of the experiment. Hence a positive number indicates an increase in the Anxiety levels and a negative number, a decrease in the Anxiety levels. Anxiety is used here also in the context of arousal with high anxiety indicating also a possible high arousal level.

Below are the means table along with the bar chart of the responses (Graph 7.1). We can observe from the graph that both the Negative and Positive images did invoke an increase in anxiety levels. We can see that the increase is bigger for the Negative images than Positive and Neutral ones. The Neutral images, on the other hand appear to have invoked a decrease in anxiety levels.



*Graph 7.1: Mean Anxiety Scores for all Affective Conditions (CI 95 %). Anxiety scores for both Negative and Positive groups increased after image presentation, though more for the Negative group. They decreased for the Neutral group.*

To assess whether the differences were significant, a one-way ANOVA was run taking one between levels IV, Valence, with three levels Positive, Negative and Neutral.

Using boxplots, three outliers were discovered in the Negative group, one in the Positive group and one in the Neutral group. All outliers were replaced with the value closest to it. The data were normally distributed for each group as assessed by Shapiro-Wilk test ( $p > 0.05$ ). Homogeneity of variances was not violated as assessed by Leven's test of Homogeneity of Variances ( $p > 0.05$ ).

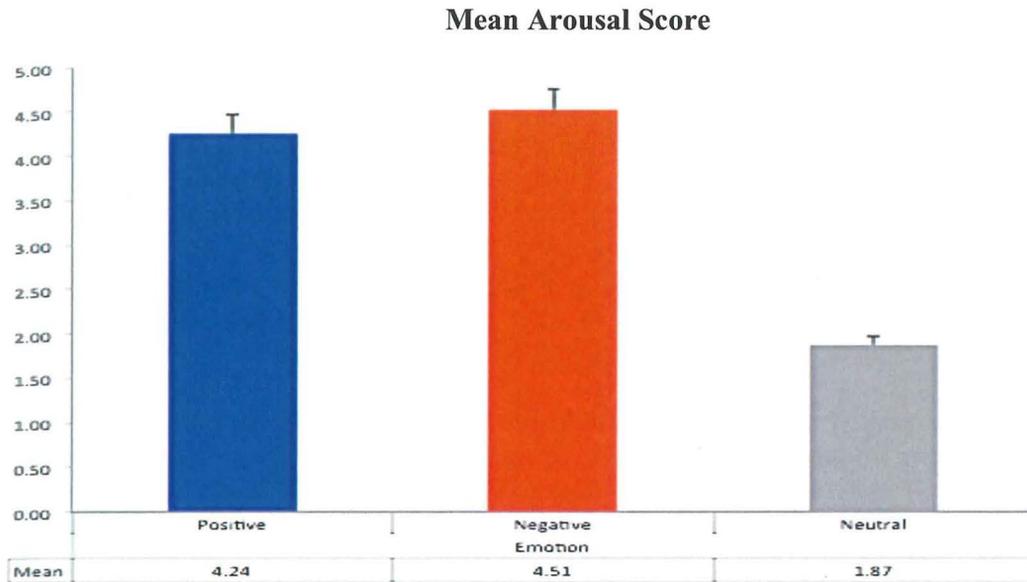
Anxiety scores were significantly different between different emotional Valence groups,  $F(2, 48) = 28.24$ ,  $p < 0.01$ . Anxiety score increased from Neutral group ( $M = -2.12$ ,  $SD = 3.94$ ) to the Positive group ( $M = 4.94$ ,  $SD = 3.34$ ) and

Negative group ( $M = 6.41$ ,  $SD = 3.30$ ) in that order. Tukey's post-hoc analysis revealed that the mean increase from Neutral to Negative (8.53, 95% CI(5.59, 11.46)) was statistically significant ( $p < 0.01$ ) as well as the increase from Neutral to Positive (7.06, 95%, CI(4.12, 9.99)),  $p < 0.01$ . There were no significant differences between the Negative and Positive Arousal scores. The results show that the emotional stimuli had the expected effect on the participants Anxiety scores with both Positive and Negative images invoking a perceived increase in Anxiety and the Neutral a perceived decrease.

#### *7.2.2.2 Result of Arousal Ratings*

Next, the results of the Arousal scores given by participants for the IAPS images were analysed. The data were added then averaged for each participant. A score closer to or one would indicate low Arousal; a score close to or 9 would indicate high Arousal. Using boxplots, one outlier was discovered in the Positive group. The outlier was replaced with the value closest to it. The data were normally distributed for all levels, except the Positive as assessed by Shapiro-Wilk test ( $p > 0.05$ ) and ( $p < 0.05$ ), respectively. Homogeneity of variances was violated as assessed by Levene's test of Homogeneity of Variances ( $p < 0.05$ ). Arousal score was significantly different between different emotional Valence groups, Welch's  $F(2, 30.81) = 68.96$ ,  $p < 0.01$ . Arousal increased from Neutral group ( $M = 1.87$ ,  $SD = .67$ ) to the Positive group ( $M = 4.24$ ,  $SD = .60$ ) and Negative group ( $M = 4.51$ ,  $SD = 1.05$ ) in that order (Graph 7.2). Games-Howell post-hoc analysis revealed that the mean increase from Neutral to Negative (2.64, 95% CI(1.89, 3.38)) was statistically significant ( $p < 0.01$ ) as well the increase from Neutral to Positive (2.37, 95% CI(1.83, 2.91)),  $p < 0.01$ . There were no significant difference between Negative and Positive groups. The results show that

the emotional stimuli had the expected effect on the participants Arousal scores with both Positive and Negative images invoking a perceived increase in Arousal levels relative to the Neutral images.

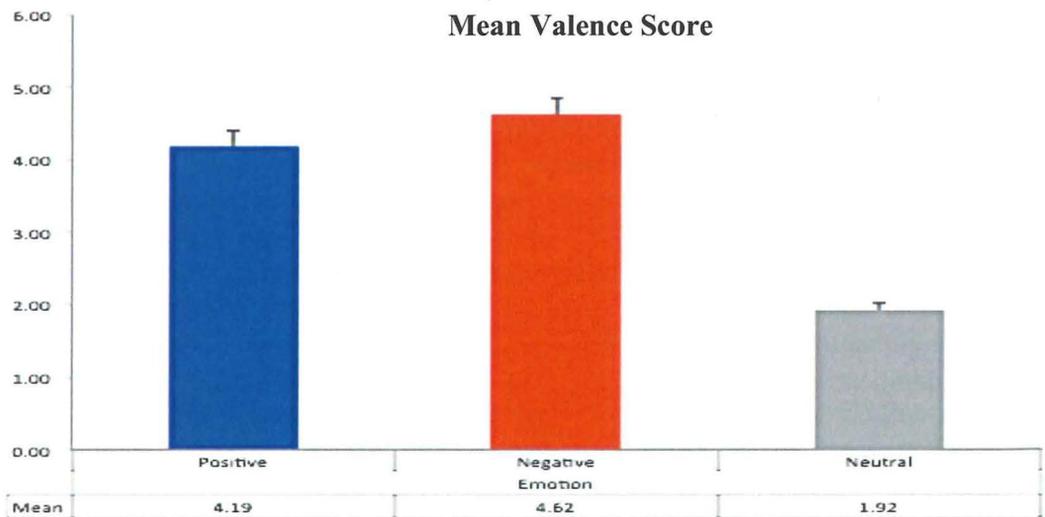


*Graph 7.2: Mean Arousal Scores for all Affective Conditions (CI 95 %).* The results from the Ratings of the Arousal scores show that participants perceived the Negative and Positive images as significantly more arousing than the Neutral images.

### 7.2.2.3 Result of Valence Measures

Next, the results of the Valence scores given by participants for the IAPS images were analysed. The data were added then averaged for each participant. A score closer to or one would indicate low emotional Valence; a score close to or 9 would indicate a high emotional Valence according to each group. Using boxplots, four outliers were discovered in the Positive group. The outliers were replaced with the value closest to them. The data were normally distributed for all levels as assessed by Shapiro-Wilk test ( $p > 0.05$ ). Homogeneity of variances was violated as assessed by Levene's test of Homogeneity of Variances ( $p < 0.05$ ).

Valence score was significantly different between different emotional Valence groups, Welch's  $F(2, 29.59) = 87.69, p < 0.01$ . The emotional valence increased from Neutral group ( $M = 1.92, SD = 0.57$ ) to the Positive group ( $M = 4.19, SD = 0.47$ ) and Negative group ( $M = 4.62, SD = 1.18$ ) in that order (Graph 7.3). Games-Howell post-hoc analysis revealed that the mean increase from Neutral to Negative (2.70, 95% CI(2.03, 3.37)) was statistically significant ( $p < 0.01$ ) as well that from Neutral to Positive (2.26, 95% CI(1.90, 3.50)),  $p < 0.01$ . There was no significant difference between Negative and Positive groups. The results show that the emotional stimuli had the expected effect on the participants Valence scores with both Positive and Negative images invoking a perceived increase in Valence levels relative to the Neutral images.



*Graph 7.3: Mean Valence Scores for all Affective Conditions (CI 95 %).* The results from the Ratings of the Valence scores show that participants perceived the Negative and Positive images as significantly more Unpleasant/Pleasant than the Neutral images.

Category 2 – Do emotions differently affect Confidence?*7.2.2.4 Result of Confidence Measures*

Next, the results of the Confidence scores reflecting the Bisection and Estimation responses were analysed. The data were added then averaged for each participant. A score closer to or one would indicate low confidence; a score close to or 4 would indicate high confidence. Using boxplots, one outlier was discovered in the Neutral group, one in the Positive group and two in the Negative group. The outliers were replaced with the value closest to them. The data were normally distributed for all levels as assessed by Shapiro-Wilk test ( $p > 0.05$ ). Homogeneity of variances was violated as assessed by Levene's test of Homogeneity of Variances ( $p < 0.05$ ). Confidence score was significantly different amongst different emotional Valence groups, Welch's  $F(2, 29.08) = 6.30, p < 0.01$ . Confidence increased from Neutral group ( $M = 2.94, SD = .52$ ) to the Positive group ( $M = 3.17, SD = .32$ ) and Negative group ( $M = 3.38, SD = .22$ ) in that order (Graph 7.4). Games-Howell post-hoc analysis revealed that the mean increase from Neutral to Negative (0.44, 95% CI(0.10, 0.79)) was statistically significant ( $p < 0.01$ ). There were no significant differences between Negative and Positive groups or Neutral and Positive groups. The confidence on answers is relatively high for all groups, all scoring over 2.5 whereas negative and positive groups scoring over 3.



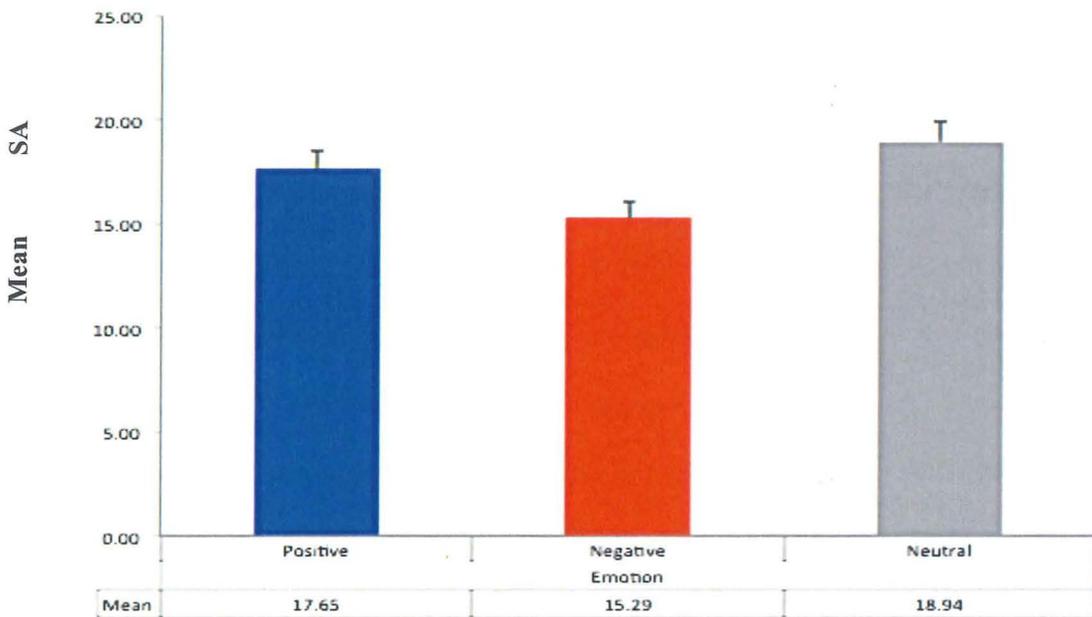
*Graph 7.4: Mean Confidence Scores for all Affective Conditions (CI 95 %).* The Confidence ratings indicate that participants were, on the whole, confident on their answers. Participants were significantly more confident on the answers given for negative images as compared to Neutral images.

### Category 3 – Do emotions differently affect Situation Awareness?

#### *7.2.2.5 Results of SA Measure*

Next, the results of the SA scores given by participants were analysed. The correct and incorrect responses were added separately for each participant. A score of 20 correct would mean 0 incorrect. The incorrect responses were subtracted from the correct responses so that a positive number indicates more correct answers were given whereas a negative number less; zero shows an equal proportion of right and wrong responses. Using boxplots, one outlier was discovered in the positive group, one in the neutral group. The outliers were replaced with the value closest to them. The data were not normally distributed on all levels as assessed by Shapiro-Wilk test ( $p < 0.05$ ). Homogeneity of variances was violated as assessed by Levene's test of Homogeneity

of Variances ( $p > 0.05$ ). SA score was significantly different between different emotional Valence groups, Welch's ANOVA  $F(2, 27.87) = 7.56, p < 0.01$ . SA score increased from Negative group ( $M = 15.29, SD = 4.06$ ) to the Positive group ( $M = 17.65, SD = 2.03$ ) and Neutral group ( $M = 18.94, SD = 1.25$ ) in that order (Graph 7.5). Games-Howell's post-hoc analysis revealed that the mean decrease from Neutral to Negative ( $-3.65, 95\% CI(-6.26, -1.03)$ ) was statistically significant ( $p < 0.01$ ). There were no differences between Negative and Positive Groups or between Positive and Neutral groups. These results indicate that Negative images had a detrimental effect on the processing of the information when compared to the Neutral images.

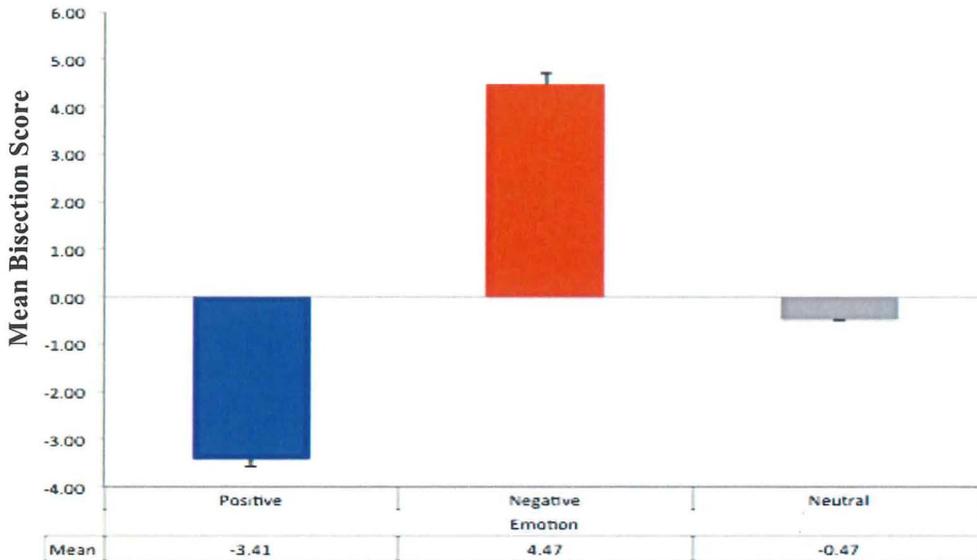


Graph 7.5: Mean SA Scores for all Affective Conditions (CI 95 %). The SA ratings indicate that participants were, on the whole worse in the negative affective condition.

Category 4 – Do emotions differently affect time perception?*7.2.2.6 Bisection Measure*

A one way, between subjects ANOVA was run with the IV the Valence with three levels, Positive, Negative and Neutral and DV the Bisection scores. The responses “Long” and the responses “Short” were added separately. The Bisection score was calculated by subtracting the sum of the responses “Short” from the sum of the responses “Long” so that a positive number show a dilation of the perception of time whereas the negative numbers show a contraction. Using boxplots, one outlier was discovered in the Neutral group. The outlier was replaced with the value closest to it. The data were normally distributed for two groups, Negative and Neutral but not Positive as assessed by Shapiro-Wilk test ( $p > 0.05$ ) and ( $p < 0.05$ ), respectively. Homogeneity of variances was not violated as assessed by Levene’s test of Homogeneity of Variances ( $p > 0.05$ ). The Bisection score was significantly different between different emotional Valence groups,  $F(2, 48) = 20.27$ ,  $p < 0.01$ . Bisection perception score increased from Positive group ( $M = -3.41$ ,  $SD = 2.98$ ) to the neutral group ( $M = 0.47$ ,  $SD = 3.20$ ) and negative group ( $M = 4.47$ ,  $SD = 4.56$ ) in that order (Graph 7.6). Tukey’s post-hoc analysis revealed that the mean increase from neutral to negative (4.94, 95% CI(1.92, 7.97)) was statistically significant ( $p < 0.01$ ) as well as the increase from positive to negative (7.88, 95%, CI(4.86, 10.91)),  $p < 0.01$ . There were no significant differences between the neutral and positive Bisection scores though they approached significance (2.94, 95%, CI(-.08, 5.97)),  $p = .06$ . The results confirm the main hypothesis that Negative emotional stimuli are related to a perceived dilation of time perception and positive to a perceived contraction ( as the difference between the positive and neutral images approached but not reached

significance, this is obviously a less supported statement) relative to the Neutral stimuli.

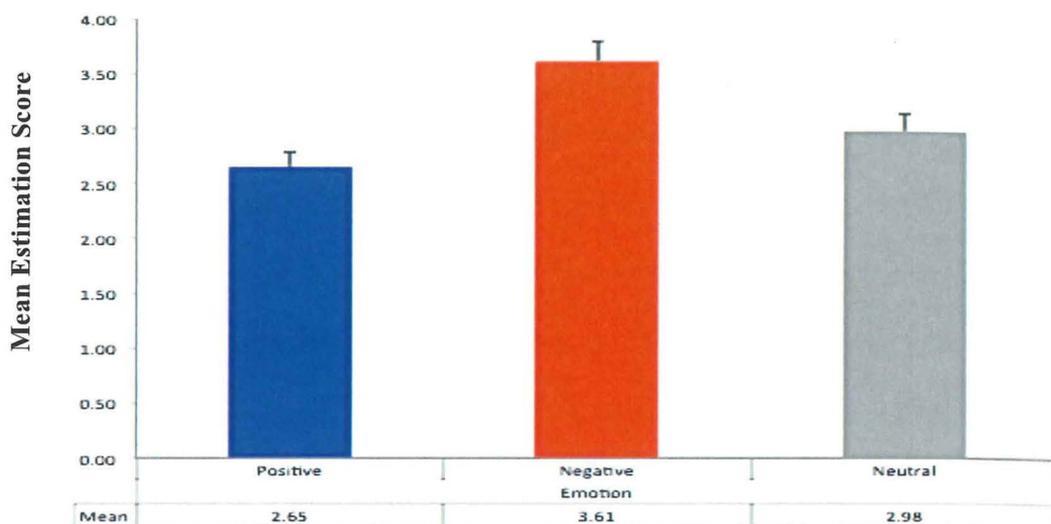


*Graph 7.6: Mean Bisection Scores for all Affective Conditions (CI 95 %). A positive number indicates a dilation of time perception, a negative score, a contraction. The data shows that Negative images did induce a dilation of Time Perception and Positive images a contraction relative to the Neutral images (the difference between the Positive and Neutral images approached significance).*

#### 7.2.2.7 Estimation Measure

The data for the Estimation score were added then averaged for each participant. A score closer to or one would indicate a short duration Estimation; a score close to or six would indicate a long duration Estimation. No outliers were discovered using boxplot. The data were normally distributed for two groups, Positive and Neutral but not Negative as assessed by Shapiro-Wilk test ( $p > .05$ ) and ( $p < .05$ ), respectively. Homogeneity of variances was not violated as assessed by Leven's test of Homogeneity of Variances ( $p > .05$ ). Since the data were not normally distributed at

all levels, both Kruskal-Wallis and ANOVA tests were run. Since the results were comparable, ANOVA results are reported.



*Graph 7.7: Mean Estimation Scores for all Affective Conditions (CI 95 %).* The data shows that Negative images did induce a dilation of Time Perception and Positive images a contraction relative to the Neutral images (the difference between the Positive and Neutral images approached significance).

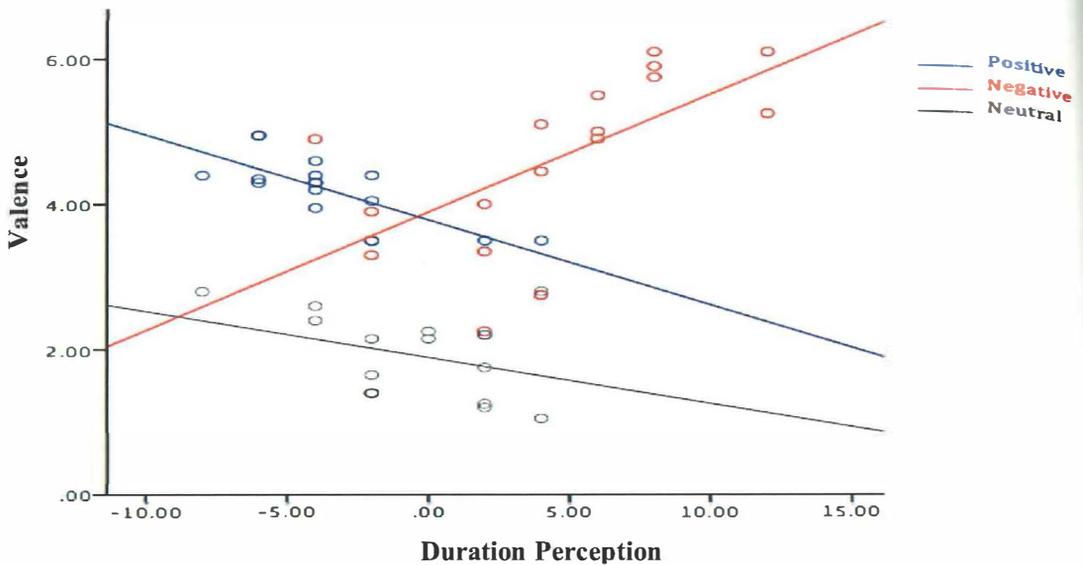
Estimation of Duration score was significantly different between different emotional Valence groups,  $F(2, 48) = 21.36, p = .00$ . Estimation of Duration score increased from Positive group ( $M = 2.65, SD = .47$ ) to the Neutral group ( $M = 2.98, SD = .40$ ) and Negative group ( $M = 3.61, SD = .44$ ) in that order (Graph 7.7). Tukey's post-hoc analysis revealed that the mean increase from Neutral to Negative (.63, 95% CI(.27, .99)) was statistically significant ( $p = .00$ ) as well as the increase from Positive to Negative (.96, 95%, CI(.60, 1.32)),  $p = .00$ . There were no significant differences between the Neutral and Positive Duration perception scores though they approached significance (.33, 95%, CI-.03, .69)),  $p = .08$ .

#### 7.2.2.8 Correlation Between Valence and Time Estimation

Since the data are not normally distributed for the Positive group in the Bisection measure (see above), a Spearman's Rank Order correlation was run to assess the relationship between Bisection scores and Valence scores. Preliminary analysis showed the relationship to be monotonic, as assessed by visual inspection of a scatterplot.

There was a strong positive correlation for the Negative group between the perception of the duration of time, as shown by the Bisection score, and perceived strength of Valence of the images,  $r_s(15) = .80, p = .00$ .

There was a strong negative correlation for the Positive group between the perception of the Duration of time and perceived strength of Valence of images,  $r_s(15) = -.72, p = .00$ . There was no significant correlation between Estimation of time and perceived strength of Valence of images for the Neutral group,  $r_s(15) = -0.33, p = .20$ . The correlation suggest that there is relationship between the time perception and the emotional Valence with the increasing degrees of Negative emotional Valence leading to increased dilation of the perception of time, and increasing degrees of Positive emotional Valence leading to increased contraction of the perception of time relative to the Neutral (Graph 7.8).



*Graph 7.8: Correlation Between Valence and Time Estimation.* The graph shows a Positive correlation between the Perceived duration and rated Valence of the Negative Images. The correlation is reversed for the Positive images.

### 7.3 DISCUSSION

The results of this experiment support our experimental hypotheses. We found a statistically significant effect of emotional Valence on time perception. Positive emotions appeared to speed up the experience of time while, in contrast, negative emotions produced the opposite effect; time was experienced as slowing down. Also, we found that negative emotional Valence was correlated to poorer image processing, whereas, in contrast, positive emotional Valence was correlated to a better image processing. The latter results are congruent with the results from the first experiment where increased negative emotions seemed to lead to poorer SA.

The results on the STAI scores showed that the emotional stimuli had the expected effect on the participants. Arousal scores with both positive and negative images did invoke a perceived increase in Arousal scores and a perceived decrease of Arousal for the neutral images. These results were further supported by the participants' self-rating scores, which also showed that the emotional stimuli had the

expected effect on the participants. Arousal scores with both positive and negative images did appear to invoke a perceived increase in Arousal levels relative to the neutral images. Participants appeared to be overall confident in their answers, all scoring in average above the 2.5 in a scale of 1 (low confidence) to 4 (high confidence) with the positive and negative. The confidence ratings indicate that participants were, on the whole, confident on their answers. Participants were significantly more confident on the answers given for negative images as compared to neutral images suggesting that the negative images, in particular, had the largest effect on participants' confidence in their answers.

The data did show that negative images did induce a dilation of time perception and positive images a contraction relative to the neutral images (the difference between the positive and neutral images approached significance) in both measures with regard to the referents and the direct estimations. The negative images seemed to have had the largest effect in distorting time perception, especially since they were also perceived to be the most accurate answers, as indicated by the confidence scores.

Also, and importantly, the correlation suggests that there is a strong relationship between the time perception and the emotional valence with the increasing degrees of negative emotional valence leading to increased perception of time dilation, and increasing degrees of positive emotional valence leading to increased perception of time contraction relative to the neutral.

Taken together, there is strong evidence to support the conclusion that the Valence of emotional arousal affects, or is affected by, the variations in the time perception. Concurrent with James & Lange's theory of emotions (i.e. James 1890), as well as Damasio's (1994, 1999), it could well be that the variations in time

perception may reflect different degrees of involvement of the body's afferent neural pathways which then result in the feeling of an emotion. This is conjecture at this point however, there is some evidence which support this hypothesis.

Khoshnoodi et al., (2008) as well as Treisman & Brogan (1992) have both reported that simply increasing the frequency of stimulus presentation leads reliably to an over-estimation of time. At the same time, exposing participants to the emotionally negative stimuli also leads to an over-estimation. If the perceptual and autonomic systems are activated to a relatively higher degree, this could be what underlies both the dilation in time perception as well as an associated negative feeling. It would be interesting to test whether differing frequencies of stimulus presentation affect the way emotional stimuli are perceived in terms of their Valence, since this has not been directly tested so far.

There has been an increased interest in the relationship between emotion and time perception but, as Lake & LaBar (2011) conclude, there has been little attempt to link this research directly to affective sciences. An important question is how perception of time is distorted in anxiety-provoking situations and the effects that that has in the in other processes of cognition, such as perception, learning and decision-making. The results of this experiment do through some light on the relationship between the two but much more research is needed.

Having found support for the relationship between the variations in time perception and the emotional Valence, next we turn our attention to shorter, millisecond time scales. If the same effect is found on shorter time scales then we can further narrow down our attention to the possible EEG correlates of the variations in time Perception and their associated emotional Valences.

## **Chapter 8 – Investigating the Sub and Supra-Second Timing Mechanisms and Their Underlying Neural Circuits**

### 8.1 INTRODUCTION

The evidence presented in the previous chapter suggests that the experience of time varies in a predicted direction as a function of the valence of emotional stimuli with the Negative emotional stimuli being highly positively correlated with the perceived durations and the Positive stimuli highly negatively correlated for referent durations 3 and 9 seconds with comparison duration of 6 seconds. Furthermore, it was found that the SA, as assessed by memory recall score on emotional images, was significantly impaired for negatively valenced images compared to positively valenced ones. These findings suggest that variations in the valence of emotional stimuli, variations in SA and variations in the perception of time may be cognitively and neurologically linked. This possibility is further explored here and the next chapter.

In this chapter we will discuss some of the evidence coming from neuroscience research, which implicates distinct brain areas and neurotransmitter systems as important for the perception of time, such as the cortical (i.e. motor and pre-motor areas) and subcortical (i.e. Basal Ganglia) and the Dopaminergic (DA) systems (Meck 1966). Furthermore, evidence will be assessed that there are partly distinct neural circuits that are responsible for milliseconds, seconds-to-minutes as well as the circadian range timings and that this distinction is somewhat blurred around the 1 second interval range (Buhusi & Cordes, 2011). Finally, evidence will be discussed that suggest that timing mechanisms in the brain may underlie other important functions such as learning, memory encoding and emotional processing.

### *8.1.1 Exploring Different Neural Circuits Underlying Different Aspects of Interval Timing*

A vast array of brain areas have been implicated in the neural contributions to Time Perception on millisecond to second intervals, both cortical (parietal, premotor, prefrontal, and insular cortices) and sub-cortical (basal ganglia and cerebellum) (Buetti 2011). Buhusi & Meck (2005) suggest that there are two main functionally separate Neural Circuits involved in processing interval timing information: an automatic timing system and a cognitively controlled timing system; the automatic system is mainly underlined by the activity around the motor and premotor circuits (Treisman, Faulkner & Naish, 1992) and the cognitively controlled system relies mainly in prefrontal and parietal regions (Lewis & Miall, 2003). Dividing many studies of time representation according to three general task characteristics: the duration measured, the use of movement to define a temporal estimate, and the continuity and predictability of the task, Lewis & Miall (2003) found that different durations were related to different psychophysical correlates. One of these differences related specifically different patterns of brain activation to the measurement of sub-second (timing intervals shorter than 1000 milliseconds) and supra-second timing intervals (timing intervals longer than 1000 milliseconds). It appears that the length of time being judged involves different stages of neural and cognitive activations.

Current pharmacological research suggests that different stages of temporal processing may also be modified by different neurotransmitter systems. For example, the internal clock used to time durations in the seconds-to-minutes range appears linked to dopamine (DA) function in the basal ganglia, while temporal memory and attentional mechanisms appear linked to acetylcholine (ACh) function in the frontal

cortex. These two systems are connected by frontal-striatal loops, thus allowing for the completion of the timing sequences involved in duration discrimination (Meck 1996).

Taking a relatively novel approach Gooch, Wiener, Hamilton & Coslett (2011) studied the differences in brain activation of sub and supra-second timing by using a voxel- based lesion-symptom mapping. The important aspect of this method is that it is essentially blind to which areas may prove to be important hence completely avoiding any potential experimenter bias (Buhusi & Cordes, 2011). Gooch et al., (2011) reported that lesions in frontal or parietal cortices led to less accuracy in Time Perception as compared to controls and that the right hemisphere, but not the left, was involved in both sub and supra-second timing. Interestingly, for the sub-second timing the additional activity of the left hemisphere was required suggesting that sub-second timing requires left-hemisphere structures, implying that sub-second timing might require a specialized neural circuitry (Buhusi & Cordes, 2011). In addition, reviewing single unit activity recordings in monkey's Pre-Frontal Cortex, Oshio (2011) suggested that PFC neurons may be involved in the monitoring of cue duration and memory encoding of the temporal aspects of the information.

Furthermore, Portugal, Wilson & Matell (2011) recorded from the striatal neurons of rats that were trained to perform a temporal reproduction task and found that their activity (91% of neurons involved in timing) was further modulated by the motor behaviour. Portugal et al., (2011) concluded that temporal information within the striatum is embedded within its contextual and motor functions. Besides its involvement in the preparation and execution of motor functions, the pre motor cortex also, more specifically the ventral pre motor cortex, is involved in supporting perceptual decisions, monitoring performance and uses "*recent and long-term sensory*

*memory to decide, execute, and evaluate the outcomes of the subjects' choices*” (Pardo-Vazquez, Padron, Fernandez-Rey, & Acuna 2011).

Although the neural correlates that underpin the inter-individual variability on time estimation are not really understood, there is evidence that it also depends on the scale of the temporal durations (Gilaie-Dotan, Kanai & Rees 2011). Gilaie-Dotan and colleagues investigated the differences on brain activity between estimations of 2 second and 12 second intervals and found that the gray matter volume in both the right posterior lateral sulcus encompassing primary auditory and secondary somatosensory cortex, plus parahippocampal gyrus strongly predicted an individual's ability to discriminate longer durations of 12 seconds but not 2 seconds regardless of the stimulus modality. The results suggest that the aforementioned brain structures are involved in modality-independent time discrimination.

Although the neural circuits involved in the sub and supra-second timing overlap, a broad categorisation would link the sub-second timing with the circuits that underlie movement preparation and execution such as motor and pre-motor areas, basal ganglia as well as the right and left prefrontal cortex whereas the supra-second timing seems to be controlled largely by frontal lobe areas (including the prefrontal cortex), parahippocampal gyrus as well as the basal ganglia. Within the context of this chapter, it is interesting to investigate the effects of judging different durations of differently valenced stimuli around the 1000 millisecond time interval as, it is suggested, it is around this time interval that both system contribute thus suggesting an increased contribution from frontal, prefrontal and subcortical areas around this time.

### 8.1.2 Exploring Different Cognitive Processes Underlying Different Aspects of Interval Timing

It has been suggested that processes of Time Perception may be an important medium for the translation of signals across the multimodal sensory processes, specifically from the visual to auditory modality, as the latter is deemed to be dominant in temporal processing (Buetti 2011). There is not much experimental support for this idea, but, nonetheless, if experimental support were to confirm this, then the implications for the cognitive mechanisms of time perception are profound. It suggests that temporal processing mechanisms, besides handling temporal information, also provide, in a sense, the medium of the synchronization of information between sensory modalities. The idea of cognition relying in the synchronization of multiple sites supporting multiple functions is not new. Damasio (1994), for example, suggests that a crucial quality of cognition is its reliance on the synchronized activity of multiple brain regions. In any synchronization, temporal information is crucial hence malfunctions of cognitive processes or brain region concerned with time perception may have widespread, damaging effects. Damasio (1994) states: *Any malfunction of the timing mechanism would be likely to create spurious integration and disintegration. This may indeed be what happens in states of confusion caused by head injury, or in some symptoms of schizophrenia and other diseases.*" (p.95). Nonetheless, though the idea is seductive, it requires much more empirical evidence before it can be explored in that context.

### *8.1.2.1 Recent Evidence on the Link of Emotions and Time Perception*

Droit-Volet, Fayolle & Gil, (2011) recently tested a paradigm, (the structure of which is similar to the one on the first experiment of this thesis), on measuring the link between emotions and time perception. Instead of asking participants to judge the duration of emotional stimuli of various arousals or valences, they instead induced a particular emotional mood by asking participants to watch a fear-inducing, sadness-inducing or neutral movie; Droit-Volet and colleagues assessed the mood induced by administering, before and after, the Brief Mood Introspective Scale. They administered a temporal bisection task before and after watching the movie and reported that fear-inducing movie alone, which was judged to provoke an increase in fear and arousal levels, did lead to an over-estimation of durations.

Reviewing studies that link emotions with the variation in time perception, Schirmer (2011) has proposed that stimulus-specific sentient representations may mediate emotional influences on the Perception of Time. Also, there is evidence that temporal ambiguity or unpredictability increases anxiety levels and is accompanied by an increase in activity of Amygdala, which, again, may account for the distortions in interval timing (Lake, & LaBar, 2011). Amygdala, which is heavily connected with both cortical and subcortical areas (Sah, Faber, Lopez de Armentia, & Power, 2003), including the striatum (Davis & Whalen 2001) may be a prime area by which the perception of time is affected by emotional stimuli.

In a reproduction study reported by Lambrechts, Mella, Pouthas. & Noulhiane (2011), content bearing stimuli (Pleasant, Unpleasant and Neutral images selected from IAPS) versus content deprived stimuli (gray squares) was also reported, to have a differential effect on time perception for different time scales. Lambrechts et al., (2011) reported that at 2 s, the reproduced duration was longer for content-bearing

than content-deprived stimuli. For 4 s and 6 s, an inverse relationship was reported between stimulus duration and differences on the time perception of content-bearing versus content-deprived stimulus with the 6 s not showing a significant difference. However, at all durations, Lambrechts et al., (2011) report, the precision of the reproduction was greater for non-emotional than emotional stimuli (pleasant and unpleasant). Again, this supports the idea that emotional stimuli affect our perception of time, however, since the direction of the distorted precision is not given, we may assume that it was somewhat random; unlike what was found in the previous experiment (Chapter 7) of this thesis.

The following experiment will further expand on the previous experiment (Chapter 7) by testing for sub (under 1000 ms) and supra-second (over 1000ms) interval timing in conditions of negative, positive and neutral affective conditions. Participants will be asked to judge a duration of a target stimuli of a positive, negative or neutral valence with reference to two referent stimuli. The referent stimuli will be set at 400ms and 1600ms. The target stimuli will be spread over 6 durations: 600, 800, 1000, 1200 and 1400ms. Due to the additional involvement of the brain areas processing emotion, it is predicted that, in particular, supra-second timing will show that negative images will slow down the perception of time and positive images speed it up relative to the neutral images, as was found in the previous experiment. The sub-second timing, on the other hand, is not clear whether it would be affected in the same way since the time for evaluating the emotional content of the images is rather short. The biggest effect is expected to be found around the 800 to 1200ms interval since that is the area where the stimuli are close to being equidistant from each referent interval hence the decision space is more ambiguous.

## 8.2 EXPERIMENT 7 – INVESTIGATING THE ROLE OF DIFFERENT AFFECTIVE CONDITIONS IN THE PERCEPTION OF TIME IN SUB AND SUPRA-SECONDS TIME INTERVALS

### 8.2.1 Method

#### 8.2.1.1 Participants

Twenty-one participants were randomly selected (opportunity sampling) mainly from students of the first, second and third year of the psychology course at the University of Gloucestershire (mean age = 27.24, SD = 10.45, 12 female, 19 right handed).

#### 8.2.1.2 Materials

##### Stimulus Presentation Computer

The same equipment was used as the equipment used in experiment 2.

##### Apparatus

Each session involved the administration of a computerised Time Estimation task, provided by the experimenter. Sessions took approximately 30-40 minutes.

##### Spielberg State Anxiety Inventory

The same questionnaire as used in experiment 1.

##### International Affective Picture System images (IAPS)

One hundred and eighty (180) colored images were pooled from the IAPS consisting of 60 pleasant, 60 neutral, and 60 unpleasant images, based on normative pleasure and arousal ratings. Pleasant images included erotic couples and happy families; neutral images included neutral faces and household objects; unpleasant images included mutilated bodies and scenes of attack and threat. Pleasant and unpleasant images were selected to be the most arousing exemplars in each gender Category, Male and Female; normative ratings of valence and arousal for the same pictures in the male and female categories differed – in other words and to take an obvious example, an image of an attractive female or male may not elicit the same emotional reaction in both genders. Ninety, of the 180 images, were chosen on Female Arousal and Valence ratings, the other on Male Arousal and Valence ratings.

Both Male and Female image Categories were further organised into five Image Groups containing 18 images each. Each of the five Image Groups were later on presented at one of five pre-set Durations of 600, 800, 1000, 1200 and 1400ms, therefore representing 2 sub-second Duration groups, 2 supra-second and one in the actual 1000 millisecond interval. Within each of the Image Groups there were three Image Sets, each containing 6 Positive images, 6 Negative images and 6 Neutral images. Based on the normative ratings of Arousal, the images were distributed so that the arousal values did not significantly differ between the same Sets compared across Image Groups, different Durations and Categories (Table 8.1).

#### **IAPS images Female Sets**

5. *Positive Set (n = 30)*: 1710, 2347, 2150, 2165, 5833, 2058, 2045, 5910, 8190, 7330, 1811, 2209, 8470, 8420, 8200, 8370, 4626, 8185, 8080, 4614, 8499, 8501, 4525, 4640, 4575, 2208, 4542, 4660, 8034, 5629.

6. *Neutral Set (n = 30)*: 7490, 7026, 5740, 7187, 7052, 7100, 7950, 7035, 7004, 7080, 7185, 7000, 7041, 5471, 7217, 7175, 7020, 2397, 7010, 2190, 2840, 7059, 7031, 7491, 7705, 7150, 7110, 5130, 7060, 9360.
7. *Negative Set (n = 30)*: 9421, 2800, 9140, 9420, 9301, 9326, 9435, 3350, 3103, 9185, 3191, 3180, 3230, 3225, 2205, 9325, 9253, 3016, 9405, 2703, 9921, 6563, 2095, 3059, 3131, 9433, 3015, 3168, 9075, 3068.

### **IAPS images Male Sets**

1. *Positive Set (n = 30)*: 4250, 4210, 4180, 5833, 8501, 8190, 5825, 1710, 1440, 1750, 4220, 4150, 1460, 4008, 4680, 5700, 8170, 8370, 4660, 8510, 4225, 4310, 4142, 8499, 4668, 8185, 4001, 4697, 8179, 4770.
2. *Neutral Set (n = 30)*: 7165, 7140, 7052, 5471, 7080, 7026, 7100, 5740, 7020, 7233, 7041, 7009, 7090, 7010, 7000, 2840, 7004, 7187, 7185, 7035, 7175, 7705, 7040, 7217, 7950, 7110, 7025, 7224, 5130, 7031.

3. *Negative Set* ( $n = 30$ ): 9252, 3500, 3068, 3059, 6313, 6350, 3030, 6570, 9413, 3140, 3010, 6563, 3069, 3110, 3001, 3530, 3071, 9183, 9410, 3060, 9940, 3130, 3100, 3120, 3170, 3000, 3131, 3080, 3102, 3053.

	Durations	Female		Male	
		Valence (mean/sd)	Arousal (mean/sd)	Valence (mean/sd)	Arousal (mean/sd)
Positive	600ms	7.98 / .38	5.78 / .67	7.82 / .39	6.67 / .44
	800ms	7.91 / .31	6.01 / .11	7.76 / .37	6.63 / .82
	1000ms	7.84 / .39	6.25 / .74	7.74 / .37	6.29 / 1.22
	1200ms	7.81 / .38	5.87 / .52	7.66 / .41	6.42 / .84
	1400ms	7.76 / .38	5.85 / .57	7.57 / .51	6.11 / 1.20
Negative	600ms	1.67 / .21	6.32 / .59	2.13 / .30	6.85 / .36
	800ms	1.56 / .17	5.95 / .56	2.11 / .30	6.66 / .21
	1000ms	1.62 / .20	5.88 / .21	2.06 / .30	6.33 / .39
	1200ms	1.60 / .20	6.48 / .24	2.03 / .30	6.23 / .23
Neutral	1400ms	1.57 / .24	6.04 / .86	2.00 / .33	6.33 / .50
	600ms	5.08 / .33	2.44 / .33	5.04 / .44	2.49 / .72
	800ms	5.00 / .28	2.36 / .18	4.99 / .40	2.56 / .33
	1000ms	4.96 / .28	2.61 / .16	4.91 / .36	2.55 / .47
	1200ms	4.90 / .34	2.30 / .32	4.88 / .36	2.45 / .74
	1400ms	4.85 / .40	2.64 / .12	4.83 / .41	2.29 / .40

*Table 8.1: Normative Means and Standard Deviations for All Affective Conditions in Each Group.* The pictures from each Category, male and female, were further subdivided into five Image Groups each later on presented at one of the following durations, 600, 800, 1000, 1200, 1400 milliseconds. All Image Groups between males and females were matched for arousal and valence ratings so that there were no significant differences. Within each Image Group, the ratings for arousal were also matched for the Negative and Positive image Sets (see statics below). Means and standard deviations for each Image Sets within Each Image Group for both Categories, male and female, are shown above.

A 5 (Durations: 600, 800, 1000, 1200 and 1400ms) by 3 (Valence: positive, negative and neutral images), between factors ANOVA revealed neither statistically significant interaction nor main effects between gender and image groups for the Arousal levels. Therefore, only the valence differed.

### *8.2.1.2 Design*

The main part of this study utilises a within subjects experimental design with two independent variables (IV): (1) Durations with 5 levels (Table 1) and (2) Emotional Valence, which has 3 levels, Positive, Negative and Neutral.

The task has 90 trials overall. To assess the Perception of durations and Arousal and Valence levels associated with each image presented in each trial, four questions were asked at the end of each image presentation assessing the perceived Durations, Confidence in their judgments, and Valence and Arousal ratings for each IAPS image. The Confidence question was included to assess the participants' confidence in their responses to their perceived time intervals. The other two DVs were used to measure the actual, as opposed to normative, measures of valence and arousal ratings for each of the participants. This would be used as a control measure to ensure the IAPS images were perceived negative, positive or neutral according to the image.

### *8.2.1.2 Procedure*

After giving informed consent, participants were led into a softly lit room and asked to sit in a reclining chair. Prior to starting the test, a verbal description of the experiment was given. The test itself was presented entirely on the computer screen and the experimenter was absent throughout the duration of the task. Participants were asked to follow instruction from the computer screen. While the experiment was running, the experimenter was located in an adjacent room. Upon finishing the task, participants were instructed to ring a bell to notify the experimenter.

Adopting a prospective paradigm, participants were told at the beginning of the experimental session that their task would involve time estimation. Participants were required to judge whether the duration of an image on screen, following two referent durations, one 400ms, one 1600ms, was closer to the longer duration image or the shorter one. As indicated, the images presented varied in duration (600, 800, 1000, 1200 and 1400 milliseconds) and in valence (positive, negative and neutral).

*Step 1 – Participants anxiety was measured*

Participants were asked to complete an on-line version of State Anxiety Inventory (STAI) (Spielberger, 1989). The inventory consisted of 20 statements (e.g. ‘I am worried’). Participants responded by clicking one of four options on the computer screen (1 = not at all, 4 = very much so). The questionnaires produced a summed score, which was used to indicate state anxiety (anxiety at that present time).

*Step 2 – Participants were trained to distinguish between a short and long duration (Referents)*

Next instructions were given to participants to observe an image 6 times (Image number 7006 from IAPS set: Normative Valence and Arousal ratings were 4.61 and 2.08 for male and 5.09 and 2.58 for female respectively. Over all Valence and Arousal ratings were 4.88 and 2.33 respectively) and distinguish between two randomly presented durations, one longer, termed as LongD (1600ms) one shorter, termed as ShortD (400ms). After each image presentation, feedback was presented on screen for 1s informing the participant whether it was a LongD or ShortD.

*Step 3 – Participants were asked to distinguish between a short and long duration Referents*

Next participants were presented asked to actively distinguish whether the same, randomly presented durations of 400 and 1600ms were LongD or ShortD. Feedback was given after each attempt. At the end of this step, participants were asked to continue only if they felt confident they could distinguish between these two durations comfortably.

*Step 4 – Instructions for the rating procedures were given*

Next participants were presented with the standard IAPS adult instructions for rating procedures for Valence and Arousal respectively (Lang, Bradley & Cuthbert 1999).

*Step 5 – Main task instructions*

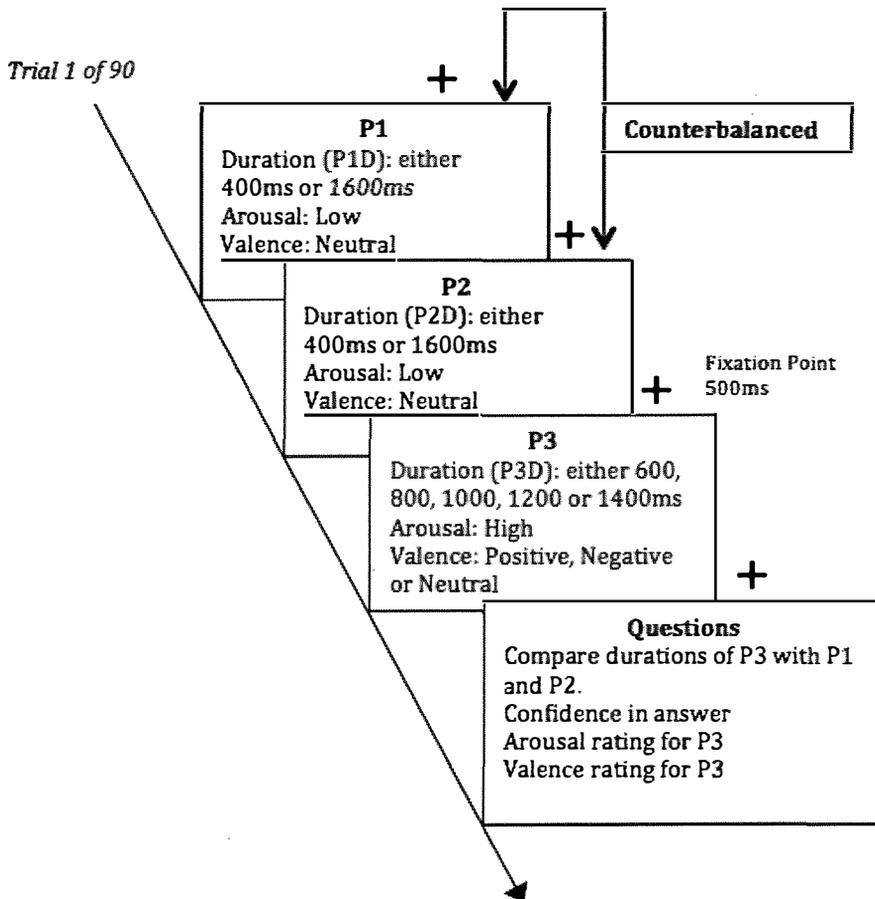
Next participants were given detailed instruction on the main task the instructions for the main task as follows:

“This is the main task and it involves 90 trials. You will be presented with three stimuli: "LongD", "ShortD" and "Photo". "LongD" and "ShortD" are the same stimuli as before. The "Photo" duration is set at random in each trial. You will be asked to decide whether the photo duration is more similar to "ShortD" or "LongD". You can use the keyboard to answer some questions at the end of each trial.”

It is important that each trial is completed correctly. Please take a quick break if you feel you are getting tired.

*Step 6 – Participants were required to judge whether a time interval of a positive, negative or neutral image presented on screen, was closer to the longer or shorter Referent.*

The main experiment started. Participants saw a fixation cross which stayed on screen for 500ms, followed by the same image encountered during training (Steps 2 and 3) with randomly but counterbalanced alternating durations of 400 or 1600ms, followed by a fixation cross followed by the other duration than the one just previously presented followed by one of the IAPS images randomly selected from the one of the Sets The participants answered the Confidence, Arousal and Valence questions after each trial (Figure 8.1).



*Figure 8.1: Main experiment structure.*

### 8.2.2 Results

#### 8.2.2.1 STAI Control Results for Genders

An independent-samples t-test was run to determine if there was a statistically significant mean difference between the state anxiety level between genders at the beginning of the experiment. There were no outliers in the data, as assessed by inspection of a boxplot. Anxiety scores for each level of gender were normally distributed, as assessed by Shapiro-Wilks test ( $p > 0.05$ ), and there was homogeneity of variances, as assessed by Levene's Test for Equality of Variances ( $p > 0.05$ ). No significant differences were found.

A further, independent-samples t-test was run to determine if there was a statistically significant mean difference between the state anxiety level between genders at the end of the experiment. There were no outliers in the data, as assessed by inspection of a boxplot. Anxiety scores for each level of gender were normally distributed, as assessed by Shapiro-Wilks test ( $p > .05$ ), and there was homogeneity of variances, as assessed by Levene's Test for Equality of Variances ( $p = .67$ ). No significant differences were found.

STAI control scores show that there were no differences between gender anxiety scores before and after the test. The first measure shows that both genders who were exposed to gender-appropriate emotional stimuli, started at similar levels of emotional arousal. Furthermore, the STAI measure after the test showed that the different images used for each gender did not have a significantly different effect on anxiety on each gender, which was the original intention.

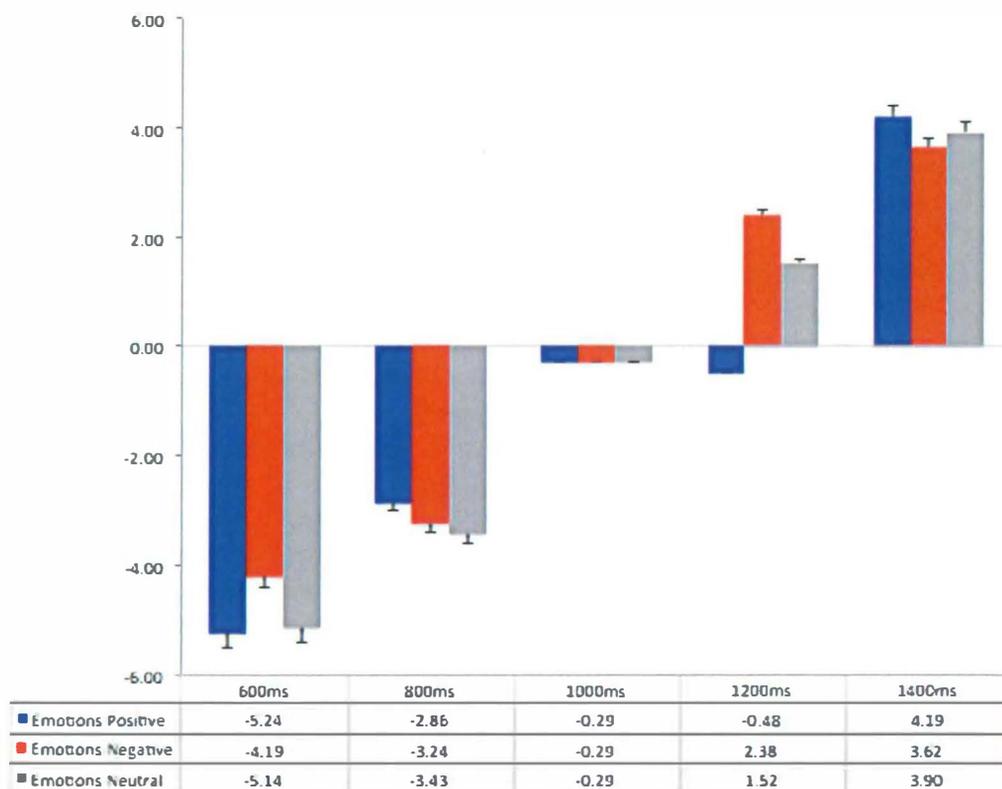
### 8.2.2.2 Results of Time Perception

The DV was the Bisection Measure and was calculated by subtracting the sum of responses “*short*” from responses “*long*”. Hence a negative number indicates a higher proportion of Short responses – contraction of time perception - and a positive number a higher proportion of Long responses – dilation of time perception. Zero means an equal number of long and short responses.

Below are the means table along with the bar chart of the responses. (Graph 8.1) The most striking difference is observed at 1200ms. Looking at the graph, we can see that even though the images are closer to the longer duration referent (the 1600 millisecond one), there is a higher proportion of “*short*” responses for the positive images and “*long*” response for the negative images.

Also, at 600ms, there is a marked difference between the perceived duration of positive and negative images. While the proportion of short responses is greater for both negative and positive images, there is a tendency to perceive negative images as comparatively longer. This appears to be reversed in the 800ms time but the differences between the three emotional Valences are smaller. At 1400ms, the differences between the three conditions are again small.

At 1000ms, the perceived durations are all the same, perceived as being slightly shorter in all of the emotional Valences.



*Graph 8.1: Mean Bisection Score for All Affective Conditions Across Different Durations (CI 95 %). The biggest difference in Duration perception for different Valences is in the 600 and 1200ms Durations.*

A 5X3 repeated measures ANOVA was conducted to determine whether there were statistically significant differences in perception of interval duration over the five different time points for different emotional Valences. Outliers were discovered using boxplot for: Neutral 600ms – 5 outliers and Negative 1200ms – 3 outliers. All outliers were replaced with the nearest value. The data was not normally distributed in all the groups except negative 1000ms, as assessed Shapiro-Wilk test ( $p < 0.05$ ). Inspection of the histograms revealed that it was not possible to transform the data to meet the normal distribution condition since different groups were skewed in different ways, some positive some negative. To control for this, the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were comparable hence the ANOVA results are reported below. The assumption of

sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.54$ ). There was a statistically significant interaction which showed that there were significant changes in duration perception over different time points for different emotionally Valenced images  $F(4.32, 86.35) = 5.03, p < 0.01, \eta^2 = .20$ .

#### 8.2.2.2.1 Post Hoc Tests

To further explore the interaction, five one way repeated measures ANOVAs taking Valence as an IV with three levels, Positive, Negative and Neutral, were run to see whether there were significant differences for each of the five durations.

For the 600ms duration, the repeated measures ANOVA was conducted to determine whether there were statistically significant differences in the perception of time for different emotional Valences. Since the data were not normally distributed at all levels, the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were comparable hence the ANOVA results are reported below. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.5$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.61$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in perception of duration of different Valences at 600ms:  $F(1.22, 24.44) = 6.84, p = 0.01, \eta^2 = 0.26$  with perception of the Duration being longer for Negative images ( $M = -4.19, SD = 2.89$ ) and shorter for Positive and Neutral images ( $M = -5.24, SD = 1.18$  and  $M = -6.00, SD = 0$  respectively). Post-hoc analysis with Bonferroni correction revealed that perception of duration differed significantly between positive and neutral ( $p < 0.03$ ) and between negative and neutral ( $p < 0.03$ ). Judging by the means, the positive

images were perceived as shorter whereas negative images were perceived as longer relative to the neutral images (Graph 8.1).

For the 1200ms duration, the repeated measures ANOVA was conducted to determine whether there were statistically significant differences in the perception of time for different emotional Valences. Since the data were not normally distributed at all levels, the data were again run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were comparable hence the ANOVA results are reported below. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.74$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in perception of duration of different Valences at 1200ms:  $F(1.47, 29.44) = 14.62, p < 0.01, \eta^2 = 0.42$ , with perception of the durations being longer for Negative images ( $M = 2.86, SD = 2.06$ ), shorter for Positive images ( $M = -0.48, SD = 2.09$ ) and in between the two for Neutral images ( $M = 1.52, SD = 3.34$ ). Post-hoc analysis with Bonferroni correction revealed that perception of Duration differed significantly between Positive and Negative ( $p < 0.01$ ) and between Positive and Neutral ( $p = 0.01$ ) (Graph 8.1).

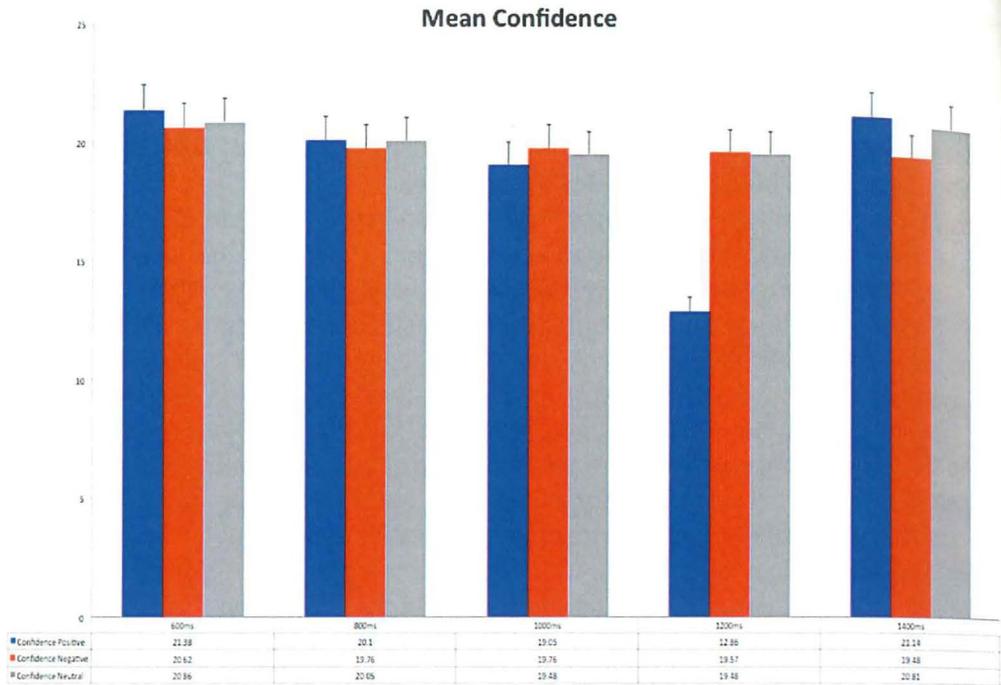
No other significant differences were found on other Durations. The data confirm the experimental hypothesis; negative images are perceived as longer and positive images are perceived as shorter in both sub and supra-second intervals. The two durations, which yielded the most significant differences, were the 600 and 1200 milliseconds, which were in the expected direction; the negative emotional stimuli slowed down the perception of time whereas positive stimuli speeded up perception of time. The results were more striking at 1200 milliseconds.

### 8.2.2.3 Results of Confidence Measures

The responses of participants were calculated by adding them up. Hence a larger number indicates a higher confidence in the answer.

Below are the means table along with the bar chart of the responses. (Graph 8.2). The most striking difference is observed at 1200ms. Looking at the graph, we can see that the confidence is lowest for the positive images. It indicates, with regard to the Bisection measure, that there was a feeling of low confidence in the answers for the positive images relative to neutral and negative images.

In all the durations, the confidence on the neutral answers is in between the confidence scores of positive and negative images and is relatively stable throughout. A 5X3 repeated measures ANOVA was conducted to determine whether there were statistically significant differences in confidence on answers over the five different time points for the three different emotional Valences. Outliers were discovered using boxplot for: Negative 800ms – 3 outliers, Neutral 800ms – 1 outlier and Neutral 1400ms – 1 outlier. All outliers were replaced with the nearest value. The data were not normally distributed in the following levels, positive 600ms, negative 600ms, neutral 600ms, negative 800ms, negative 1000ms, positive 1400ms and neutral 1400ms, as assessed Shapiro-Wilk test ( $p < 0.05$ ). Inspection of the histograms and attempts to transform the data showed that it was not possible to meet the normal distribution condition since different groups were skewed in different ways, some positive some negative. In order to control for this violation, the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test.



Graph 8.2: Mean Confidence Score for All Affective Conditions Across Different Durations (CI 95 %). The biggest difference in Confidence scores is in 1200 Duration. Confidence on the perception of the neutral images falls between those of Positive and Negative images.

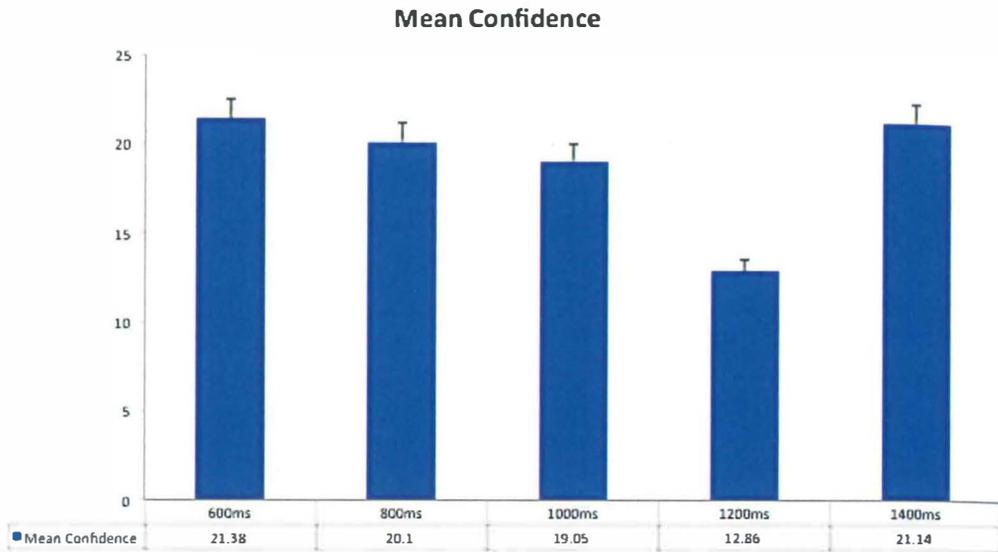
The results were comparable hence the ANOVA results are reported below. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.54$ ). There was a statistically significant interaction which showed that there were significant changes in Confidence in answers over different time points for different emotionally Valenced images:  $F(4.31, 86.17) = 31.22, p < 0.01, \eta^2 = 0.61$ .

#### 8.2.2.3.1 Post Hoc Tests

To further explore the interaction, three one way repeated measures ANOVAs taking Duration as an IV with five levels, 600, 800, 1000, 1200 and 1400 milliseconds, were run to see whether there were significant differences of confidence between five

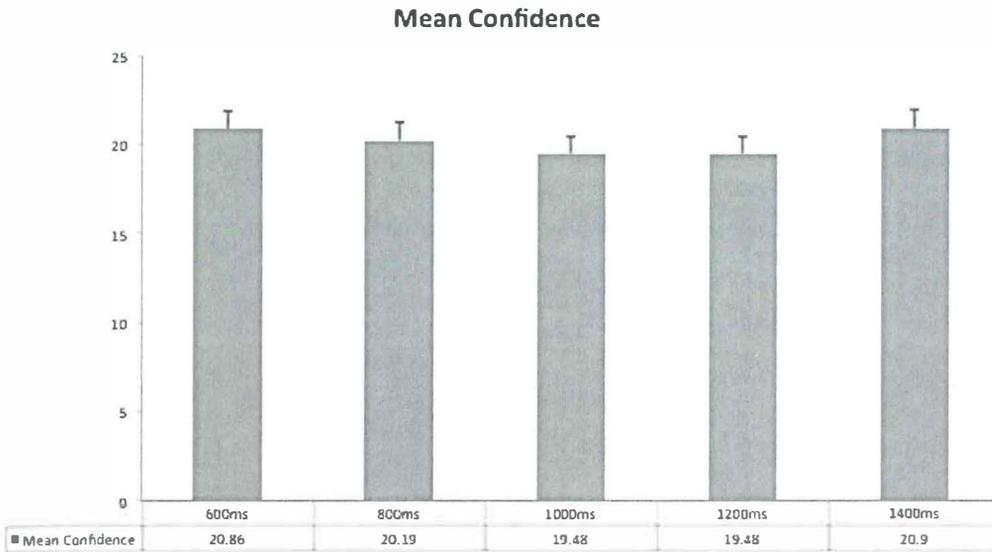
durations for each valence. Furthermore, five one way repeated measures ANOVAs were run taking Valence as an IV with three levels, positive, negative and neutral, to see whether there were significant differences in confidence for each of the five durations.

A one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in confidence for the positive images across different durations. Since the data were not normally distributed the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were comparable hence the ANOVA results are reported below. The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = .05/3 = 0.02$ . There was a statistically significant difference in the Confidence in answers for different durations  $F(4, 80) = 94.61, p < 0.01, \eta^2 = 0.83$  with a decreasing confidence from 600ms to 1200ms ( $M = 21.38, SD = 2.84; M = 20.10, SD = 2.83; M = 19.05, SD = 2.73$  and  $M = 12.86, SD = 1.80$ , respectively) but returning close to original value for 1400ms duration ( $M = 21.14, SD = 2.63$ ). Post-hoc analysis with Bonferroni correction revealed that Confidence in answers differed significantly between 1000ms and 1200ms ( $p < 0.01$ ) and between 1200ms with 1400ms ( $p < 0.01$ ). Judging by the means, the positive images invoked significantly less confidence after the 1000ms but significantly more confidence after the 1200ms (Graph 8.3).



Graph 8.3: Mean Confidence Score for Positive Affective Conditions Across Different Durations (CI 95 %). Confidence decreases from shorter durations up to 1200ms but increases again for 1400ms.

A one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Confidence for the neutral images. Since the data were not normally distributed the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were comparable hence the ANOVA results are reported below. The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = .05/3 = 0.02$ . There was a statistically significant difference in the Confidence in answers for different durations  $F(4, 80) = 3.90, p < 0.01, \eta^2 = .16$  with a the Confidence levels being greater for 600, 800 and 1400ms ( $M = 20.86, SD = 2.94$ ;  $M = 20.19, SD = 2.34$  and  $M = 20.90, SD = 2.41$ , respectively) as compared to 1000 and 1200ms ( $M = 19.48, SD = 3.06$  and  $M = 19.48, SD = 3.25$  respectively). Post-hoc analysis with Bonferroni correction did not reveal significant differences. The means show a slight decreasing trend in confidence until 1200 milliseconds (Graph 8.4). There is an increase, although slight, at 1400 milliseconds.

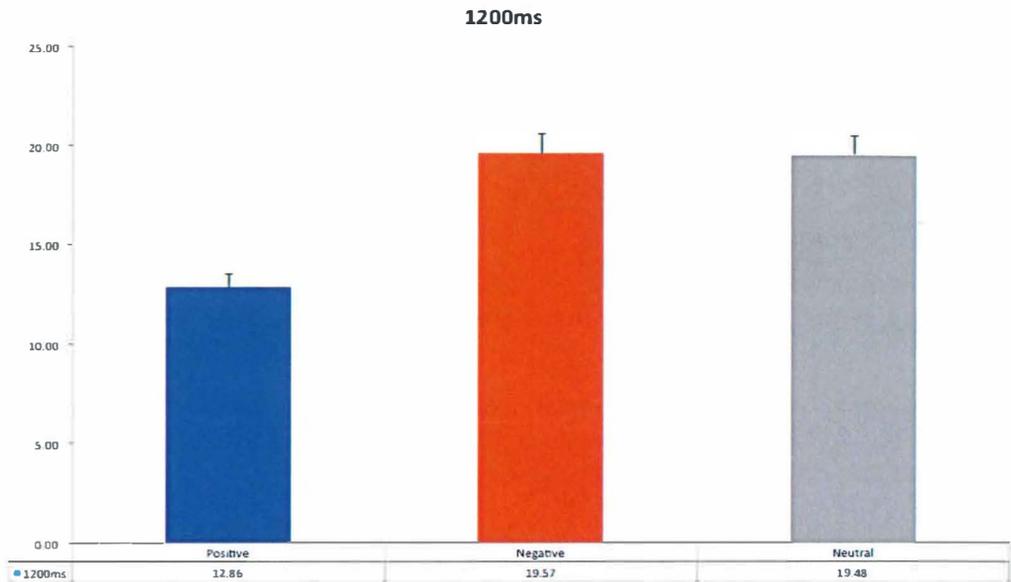


Graph 8.4: *Mean Confidence Score for Negative Affective Conditions Across Different Durations (CI 95 %)*. There is a similar trend for the neutral images to the positive images (see graph 9.3) but it is less pronounced.

A similar ANOVA was run for the negative images but no significant differences were found on the confidence levels.

A one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in confidence between different affective condition for the 1200ms duration. The data was normally distributed as assessed by Shapiro-Wilk test ( $p > 0.05$ ). The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = .05/5 = 0.01$ . There was a statistically significant difference in the confidence in answers for 1200ms duration  $F(2, 40) = 98.51, p < 0.01, \eta^2 = 0.83$  with confidence being lowest for the positive images as compared to neutral and negative images ( $M = 12.86, SD = 1.80; M = 19.48, SD = 3.25$  and  $M = 19.57, SD = 2.80$  respectively). Post-hoc analysis with

Bonferroni correction revealed that confidence in answers differed significantly between positive and negative images ( $p < 0.01$ ) and between positive and neutral images ( $p < 0.01$ ). Judging by the means, the positive images invoked significantly less confidence than both negative and neutral images (Graph 8.5).



Graph 8.5: Mean Confidence Score for All Affective Conditions for 1200ms Duration (CI 95 %). There is a similar trend for the Neutral images to the positive images (see graph 9.3) but it is less pronounced. The confidence for the Positive image durations was significantly lower at 1200 milliseconds.

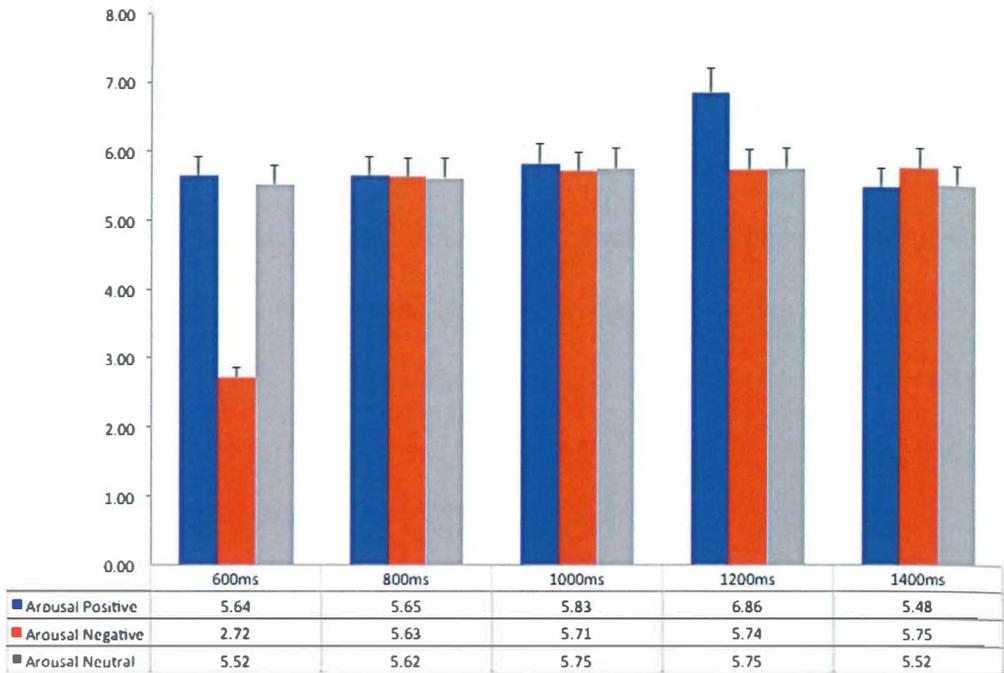
A one way repeated measures ANOVA was also conducted to determine whether there were statistically significant differences in confidence between different affective conditions at the 1400ms duration. Since the data were not normally distributed the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were not comparable, ANOVA showed a significant difference but Friedman's test showed a non significant difference hence, taking into account the non-parametric test, there were no differences in confidence for the 1400ms.

There were no other significant differences in the Confidence scores for other ANOVAs. To summarise, there was a significant interaction between different durations and affective conditions. Overall, Confidence for the negative images was stable whereas neutral and positive images invoked a U shaped dipping at 1200 milliseconds. The positive images appeared to invoke significantly less confidence than both neutral and negative images at 1200 milliseconds.

#### *8.2.2.4 Results of Valence Measures*

The responses of participants were calculated by adding them up, averaged then rescaled so that a score of 9 would mean highly pleasurable whereas a score of one would mean extremely disagreeable.

Below are the means table along with the bar chart of the responses. (Graph 8.6) Again, the most striking differences are observed at 600 and 1200ms. As expected, the graph shows that the least pleasurable images, as ratings indicate, appear to be, mostly, the negative images and the most pleasurable the positive images, especially at 600 and 1200 milliseconds.



Graph 8.6: Mean Valence Score for All Affective Conditions for All Duration (CI 95 %) – Outlier Corrected. The graph shows that overall, positive images were perceived as more pleasurable than negative images with the biggest differences at 600 and 1200 milliseconds.

A 5X3 repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings over the five different time points for different emotional Valences. Outliers were discovered using boxplot for: negative 800ms – 3 outliers, neutral 800ms – 1 outlier and neutral 1400ms – 1 outlier. All outliers were replaced with the nearest value. The data was not normally distributed in the following groups neutral 600ms, negative 800ms, negative 1000ms, positive 1400ms and neutral 1400ms, the other 10 levels were normally distributed as assessed Shapiro-Wilk test ( $p < 0.05$ ) and ( $p > 0.05$  respectively). Inspection of the histograms and attempts to transform the data showed that it was not possible to meet the normal distribution condition on all levels since different groups were skewed in different ways, some positive some negative. In order to control for this violation, the

data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were comparable hence the ANOVA results are reported below. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.26$ ). There was a statistically significant interaction which showed that there were significant changes in the Valence ratings of images over different time points for different emotionally Valenced images  $F(2.05, 41.00) = 39.78.91, p < 0.01, \eta^2 = 0.67$ .

#### 8.2.2.4.1 Post Hoc tests

To further explore the interaction, three one way repeated measures ANOVAs taking Duration as an IV with five levels, 600, 800, 1000, 1200 and 1400 milliseconds, were run to see whether there were significant differences of Valence scores between five Durations for each Valence. Furthermore five one way repeated measures ANOVAs were run to see whether the Valence scores differed within each Duration.

A one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings of the positive images across different durations. The data were normally distributed on all levels except the 1400ms one as assessed by Shapiro-Wilk test ( $p < 0.05$ ). The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.33$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/3 = 0.02$ . There was a statistically significant difference which showed that there were significant changes in the Valence ratings of positive images over different time points  $F(1.32, 26.36) = 16.04, p < 0.01, \eta^2 = .45$ . Post-hoc analysis with Bonferroni correction revealed that

Valence ratings in images differed significantly between 1000ms to 1200ms ( $p < 0.01$ ) and between 1200 and 1400ms ( $p < 0.01$ ). Looking at the table of means and the chart above (Graph 8.6) we can see that the images are rated as more pleasurable at 1200ms than both 1000ms and 1400ms.

Another one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings of the negative images across different durations. The data were normally distributed on all levels except the 800 and 1000ms as assessed by Shapiro-Wilk test ( $p < 0.05$ ). The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.34$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/3 = 0.02$ . There was a statistically significant difference which showed that there were significant changes in the Valence ratings of negative images over different time points  $F(1.36, 27.15) = 90.93, p < 0.01, \eta^2 = .82$ . Post-hoc analysis with Bonferroni correction revealed that Valence ratings in images differed significantly between 600 to 800ms ( $p < 0.01$ ). Looking at the table of means and the chart above (Graph 8.6) we can see that the images are seen as more disagreeable at 600ms than 800ms.

A further one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings of the neutral images across different durations. The data were normally distributed on 1000ms and 1200ms levels but not normally distributed in other levels as assessed by Shapiro-Wilk test ( $p < 0.05$ ). In order to control for this violation, the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. Since

the results were comparable, ANOVA tests are reported below. The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/3 = 0.02$ . There was a statistically significant difference which showed that there were significant changes in the Valence ratings of neutral images over different time points  $F(4, 80) = 3.89, p < 0.01, \eta^2 = .16$ . Post-hoc analysis with Bonferroni correction did not reveal significant differences.

For the 600ms duration, the repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings for different emotional Valences. The data were not normally distributed for the neutral group as assessed by Shapiro-Wilk test ( $p < 0.05$ ). The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = .74$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in Valence ratings at 600ms  $F(1.48, 29.49) = 46.17, p < 0.01, \eta^2 = 0.70$  with the Valence decreasing from the positive images ( $M = 5.64, SD = 1.18$ ) to the neutral images ( $M = 5.52, SD = 0.49$ ) and negative images ( $M = 2.72, SD = 1.32$ ) in that order. Post-hoc analysis with Bonferroni correction revealed that Valence ratings of positive images differed significantly from the negative ( $p < 0.01$ ) and negative differing significantly from the neutral ( $p < 0.01$ ). Judging by the means (Graph 8.6), the positive images were perceived as significantly more agreeable than negative images and negative images as significantly more disagreeable than neutral images.

For the 1200ms duration, the repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings for different emotional Valences. The data was normally distributed for all levels as assessed by Shapiro-Wilk test ( $p > 0.05$ ). The assumption of sphericity was not violated as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in Valence ratings at 1200ms  $F(2, 40) = 98.51, p < 0.01, \eta^2 = 0.83$ , with the Valence decreasing from positive images to neutral images to negative images in that order ( $M = 6.86, SD = 0.30$ ;  $M = 5.75, SD = 0.54$  and  $M = 5.74, SD = 0.47$ , respectively). Post-hoc analysis with Bonferroni correction revealed that Valence ratings of positive images differed significantly from neutral and negative images ( $p < 0.01$ ). Judging by the means (Graph 8.6), the positive images were perceived as more pleasurable than both neutral and negative and Negative images.

For the 1400ms duration, the repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings for different emotional Valences. The data was normally distributed for all levels except the neutral group as assessed by Shapiro-Wilk test ( $p > 0.05$ ). The assumption of sphericity was not violated as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in Valence ratings at 1400ms  $F(2, 40) = 5.93, p < 0.01, \eta^2 = 0.23$ , with the Valence decreasing from negative images to neutral images to positive images in that order ( $M = 5.75, SD = 0.46$ ;  $M = 5.52, SD = 0.40$  and  $M = 5.48, SD = 0.42$ , respectively). Post-hoc analysis with Bonferroni

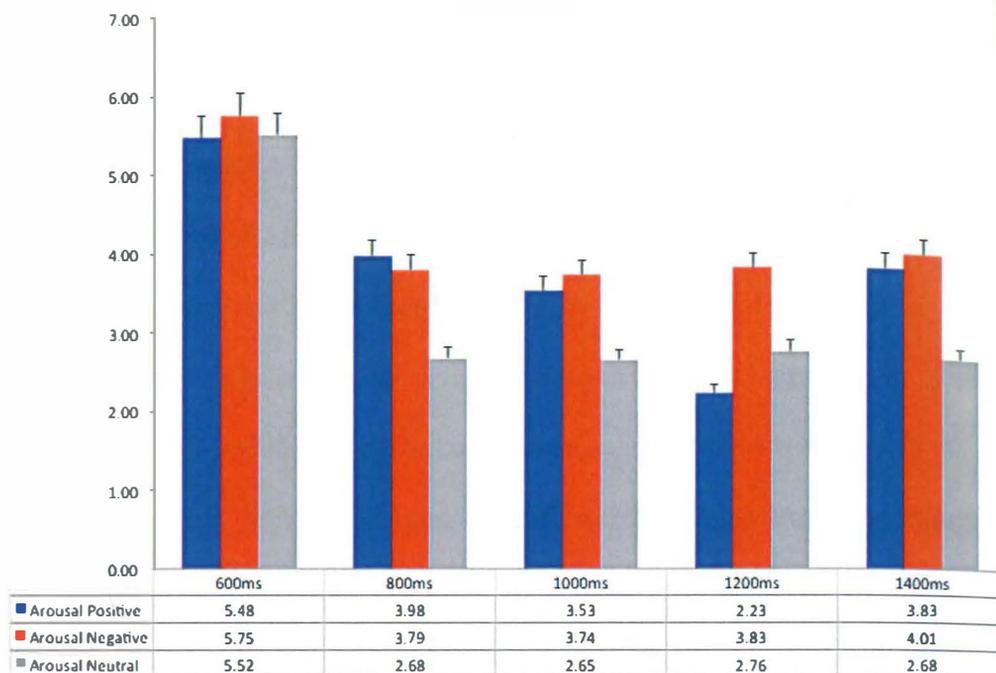
correction revealed that Valence ratings of negative images differed significantly from neutral and positive images ( $p < 0.05$ ). Judging by the means (Graph 8.6), the negative images were perceived as more pleasurable than both neutral and positive images.

As expected, the valence ratings, apart from the 1400ms, showed the positive images as more pleasurable than neutral and negative images as less pleasurable than the neutral images wherever there were significant differences. The most salient differences seem to be at the 600 and 1200 milliseconds.

#### *8.2.2.5 Arousal Measures*

The responses of participants were calculated by adding them up, averaged so that a score of 9 would mean high Arousal whereas a score of one would mean low Arousal.

Below are the means table along with the bar chart of the responses (Graph 8.7). Apart from the 1200ms time, all the other Arousal scores show an expected pattern. The negative and positive images show a generally higher Arousal rating when compared to neutral with the noticeable exception at 1200ms. Also, the bar chart shows that, again, apart from the 1200m duration, the Arousal ratings of positive and negative images are very close together. At 1200ms, the Arousal for the positive images is the lowest. The negative images appear to invoke a relatively consistent higher Arousal rating whereas the positive images appear to oscillate reaching the lowest point at 1200ms. Notice neutral images are consistently low after the 600ms and stay relatively at the same level.



Graph 8.7: Mean Arousal Score for All Affective Conditions for All Duration (CI 95 %) – (Outliers Normalised). The graph shows that overall, negative and positive images were perceived as more arousing than neutral images in all durations.

A 5X3 repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Arousal ratings over the five different time points for different emotional Valences. Inspection of boxplots revealed one outlier at the neutral group 600ms; the outlier was replaced with the value closest to it. The data was not normally distributed in the following five out of 6 levels, neutral 600ms, neutral 800ms, neutral 1000ms, neutral 1200ms, and also neutral at 1400ms as assessed Shapiro-Wilk test ( $p < 0.05$ ), all the other levels were normally distributed. Inspection of the histograms and attempts to transform the data showed that it was not possible to meet the normal distribution condition. In order to control for this violation, the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were comparable hence the ANOVA results are reported below. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied

( $\epsilon = 0.50$ ). There was a statistically significant interaction which showed that there were significant changes in the Arousal ratings of images over different time points for different emotionally Valenced images  $F(3.64, 72.74) = 10.62, p = 0.01, \eta^2 = 0.35$ .

#### 8.2.2.5.1 Post Hoc tests

To further explore the interaction, three one way repeated measures ANOVAs taking Valence as an IV with three levels, Positive, Negative and Neutral, were run to see whether there were significant differences of Arousal ratings in each of the five Durations. Five further one way repeated measure ANOVAs were run to see whether the Arousal ratings differed within each of the durations.

A one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings of the positive images across different durations. There were no outliers and the data was normally distributed on all levels as assessed by boxplot and Shapiro-Wilk test ( $p > 0.05$ ), respectively. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.41$ ). To adjust for multiple comparisons, the significance value was set to  $p = .05/3 = 0.02$ . There was a statistically significant difference which showed that there were significant changes in the Arousal ratings of Positive images over different time points  $F(1.66, 33.11) = 41.06, p < 0.01, \eta^2 = 0.67$ . Post-hoc analysis with Bonferroni correction revealed that Arousal ratings in images differed significantly between 600ms to 800ms ( $p < 0.01$ ), between 1000ms and 1200ms ( $p < 0.01$ ) and between 1200ms and 1400ms ( $p < 0.01$ ). Looking at the table of means and the chart above (Graph 8.7) we can see that the positive images invoke less arousal at 800ms

compared to 600ms, 1200ms compared with 1000ms and more arousal at 1400ms compared with 1200ms.

A one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Valence ratings of the neutral images across different durations. There were no outliers and the data was not normally distributed on all levels as assessed by boxplot and Shapiro-Wilk test ( $p < 0.05$ ), respectively. In order to control for this violation, the data were run both on ANOVA procedures and the non-parametric equivalent, Friedman test. The results were comparable hence the ANOVA results are reported below. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity ( $p < 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.29$ ). To adjust for multiple comparisons, the significance value was set to  $p = .05/3 = 0.02$ . There was a statistically significant difference which showed that there were significant changes in the Arousal ratings of negative images over different time points  $F(1.17, 23.33) = 65.42, p < 0.01, \eta^2 = 0.77$ . Post-hoc analysis with Bonferroni correction revealed that Arousal ratings in images differed significantly between 600ms to 800ms ( $p < 0.01$ ). Looking at the table of means and the chart above (Graph 8.7) we can see that the neutral images invoke significantly less arousal at 800ms compared to 600ms.

For the 600ms duration, a one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Arousal ratings of the differently Valenced images. There were no outliers and the data was normally distributed on all levels, except for the neutral as assessed by boxplot and Shapiro-Wilk test ( $p > 0.05$ ). The assumption of sphericity was not violated, as assessed by

Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = .05/5 = 0.01$ . There was a statistically significant difference in Arousal ratings at 600ms  $F(2, 40) = 5.93, p < 0.01, \eta^2 = 0.23$ . Post-hoc analysis with Bonferroni correction revealed that Arousal ratings in images differed significantly between positive and negative images ( $p < 0.05$ ) and between negative and neutral images. Looking at the table of means and the chart above (Graph 8.7) we can see that the negative images are rated as more arousing than both positive and neutral images.

For the 800ms, a one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Arousal ratings of the differently Valenced images. There were no outliers and the data was normally distributed on all levels, except for the neutral as assessed by boxplot and Shapiro-Wilk test ( $p > 0.05$ ). The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in Arousal ratings at 800ms  $F(2, 40) = 8.67, p < 0.01, \eta^2 = 0.30$ . Post-hoc analysis with Bonferroni correction revealed that Arousal ratings in images differed significantly between neutral and, both, positive and negative images ( $p = < 0.01$ ) and ( $p < 0.02$ ) respectively. Looking at the table of means and the chart above (Graph 8.7) we can see that the neutral images are rated as less arousing than both positive and negative images.

For the 1000ms, a one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Arousal ratings of

the differently Valenced images. There were no outliers and the data was normally distributed on all levels, except for the neutral as assessed by boxplot and Shapiro-Wilk test ( $p > 0.05$ ). The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in Arousal ratings at 800ms  $F(2, 40) = 4.92, p < 0.02, \eta^2 = 0.20$ . Post-hoc analysis with Bonferroni correction revealed that Arousal ratings in images differed significantly between neutral and, both, positive and negative images ( $p = < 0.01$ ) and ( $p < 0.02$ ) respectively. Looking at the table of means and the chart above (Graph 8.7) we can see that the neutral images are rated as less arousing than both positive and negative images.

For the 1200ms, a one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Arousal ratings of the differently Valenced images. There were no outliers and the data was normally distributed on all levels, except for the neutral as assessed by boxplot and Shapiro-Wilk test ( $p > 0.05$ ). The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in Arousal ratings at 800ms  $F(2, 40) = 10.58, p < 0.01, \eta^2 = 0.35$ . Post-hoc analysis with Bonferroni correction revealed that Arousal ratings in images differed significantly between positive and negative ( $p < 0.01$ ) and approach significance between negative and neutral ( $p = 0.06$ ). Looking at the table of means and the chart above (Graph 8.7) we can see that the positive images are rated as significantly less

arousing than negative images and negative images are close to significantly higher arousal ratings than neutral images.

For the 1400ms, a one way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Arousal ratings of the differently Valenced images. There were no outliers and the data was normally distributed on all levels, except for the neutral as assessed by boxplot and Shapiro-Wilk test ( $p > 0.05$ ). The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). To adjust for multiple comparisons, the significance value was set to  $p = 0.05/5 = 0.01$ . There was a statistically significant difference in Arousal ratings at 800ms  $F(2, 40) = 8.31, p < 0.01, \eta^2 = 0.29$ . Post-hoc analysis with Bonferroni correction revealed that Arousal ratings in images differed significantly between neutral and both positive and negative images ( $p < 0.01$ ) and ( $p < 0.02$ ) respectively. Looking at the table of means and the chart above (Graph 8.7) we can see that the neutral images are rated as significantly less arousing than both negative and positive images.

Measures of the Arousal showed that negative and positive stimuli invoked at most levels higher scores than neutral stimuli (except the 600ms duration). There is, however, a notable difference at 1200 milliseconds where the negative and positive stimuli seem to differ more than in other durations, with the positive stimuli invoking a lower arousal at that point.

## 8.3 DISCUSSION

The bisection scores show a highly significant interaction indicating that the perception of time across different durations differed significantly according to the different emotional stimuli. Further analysis showed that two durations yielded the most significant differences in this regard, 600 and 1200 milliseconds. The differences showed, as expected, that the negative emotional stimuli were associated with a slowing down of the perception of time whereas the positive stimuli were associated with a speeded up perception of time. The most significant results were found at the 1200 milliseconds duration for the positive images.

Even though all images at that the duration 1200 milliseconds were actually closer to the longer duration Referent (the 1600ms one), positive images were perceived as being more similar to the shorter duration Referent (400ms one). Also, at this time-point, 1200 milliseconds, there is a clear separation between the perception of the duration of the neutral images when compared to both negative and positive images, and in the predicted direction. The mean perceived duration of the neutral images is 0.86 lower than the negative and 1.04 higher than the positive. The difference at this duration between the perception of time of differently Valenced stimuli is significantly larger than in all other durations (graph 8.1). Therefore we conclude that the results of the experiment support our main experimental hypotheses, that negative and positive emotions are respectively related to a dilation and contraction of the perception of time. Although the effect seems to be larger for the supra-second interval (that is, at 1200ms), it should be noted that the relationship appears to hold for both sub and supra-second time intervals. positive emotions appeared to speed up the experience of time in the 600 milliseconds and 1200

milliseconds time intervals while, in contrast, negative emotions produced the opposite effect; time was experienced as slowing down at those durations relative to neutral images.

There was also a statically significant interaction of confidence scores between different durations and emotional Valences. While the confidence remind relatively unchanged for the neutral images through all the durations, the confidence for the negative and positive images tended to show a relatively U shaped curve dipping at the lowest point at 1200 milliseconds. This is most pronounced for the positive images that show a significant dip in confidence at 1200 milliseconds compared to before (1000 milliseconds) and after (1400 milliseconds). The perception of duration of positively Valenced images at 1200 milliseconds also invoked significantly less confidence than in neutral and negative images too.

The valence ratings, as expected, generally showed that IAPS images were perceived as expected. The most significant differences were seen at the 600 and 1200 milliseconds with the positive and negative valences showing a marked difference from the neutral images in the expected direction. Since the negative images were perceived as significantly more negative than neutrals at 600ms whereas positive images where see as significantly more positive than neutral at 1200 milliseconds, and, furthermore, negative images alone seem to significantly decreased at 600ms when compared to 800ms whereas positive images alone seem to increase in valence at 1200ms as compared to 1000 and 1400ms, it can be tentatively suggested that the effect on the sub-second time scales are more liable to be affected by the negative emotional stimuli whereas the supra-second time scales by the positive emotional stimuli.

The Arousal scores showed, as expected the negative and positive images invoked a consistently higher Arousal rating when compared to neutral. Also, the bar chart (Graph 8.6) shows that in all durations except the 1200ms and 600ms durations, the Arousal ratings of the positive and negative images are very close together. At 1200ms, the Arousal for the positive images is the lowest. The data analysis showed that Arousal levels differed significantly for different Valences across durations. Positive images at 1200 milliseconds especially invoked less Arousal levels compared with 1000ms, and 1400ms. It appears that a dip in Arousal levels at 1200 milliseconds was associated with an increased distortion of the perception of time. At 1200 milliseconds, the correct response for all questions would have been the “long” response since that duration is closer to the 1600 milliseconds than 400 milliseconds by 400 milliseconds, however, in the case of positive images, the overall responses tended to see them as closer to the shorter duration, indicating therefore a strong effect of the affective conditions, especially the positive affective condition at this point. Overall the data seems to suggest that high negative arousal at sub-second intervals has a strong effect and dilates perception of time whereas high positive arousal at supra second intervals has also a strong effect and contract the perception of time. It could be argued that negative affective stimuli are initially preferentially processed at short intervals since they may represent danger and hence avoiding such stimuli would be advantageous in evolutionary terms.

The findings here are in general agreement with Droit-Volet et al., (2011) and Lambrechts et al., (2011). With regard to the latter work, there is an interesting parallel with Eagleman (2008), which was mentioned in the previous chapter. In Chapter 7, Eagleman (2008) and a few other studies were cited (Khoshnoodi et al., 2008; Treisman & Brogan, 1992; Treisman et al., 1990) which suggest that increasing

the temporal resolution of the brain's processing of information also leads to a dilation of Time Perception – in other words, perceptual time slows down. The results here appear to confirm this, as the participants are exposed to highly negative emotional stimuli, the brain's resolution increases leading to dilation of the time perception. The interesting aspects of the results in this study are that the effect seems to happen at specific time intervals, 600 and 1200 milliseconds ones to be more precise and at this times, and negative images appear more dominant in the 600ms interval whereas positive images at 1200ms interval. Also, it is not sure why do these effects happen at symmetrical time points. At this time it is not possible to give a clear answer since the enquiry to find a plausible answer on this did not yield any particular study that could bring some light. It is, however, curious that it happens, as far as this particular set of data suggests, in time intervals that are multiples of each other therefore mathematically related.

The next chapter will focus on the supra-second time interval, since this where the biggest difference was found, to see whether changing the distance of the referents to the comparison interval makes any difference. Reducing the distance of the Referent intervals means that there is more cognitive capacity required to make the distinction. What would happen in these conditions? This question will be investigated next.

## Chapter 9 - Investigating the Decision Making Processes in Time Perception

### 9.1 INTRODUCTION

In the previous two chapters it was shown that the emotional bisection task clearly differentiates the effects that different affective stimuli has in the perception of time. Importantly, the previous experiment showed that within the same task, different, conflicting affective stimuli could differentially affect the perception of fixed time intervals thus allowing for a possible on-line evaluation of a person's perception of diverse affective stimuli by measuring its perceived length of time. The most relevant aspect of that finding, with regard to this thesis, is the possibility of using the variations on the perception of time as an indicator of a person's perception of a situation in terms of emotional valences of negative, positive or neutral. As shown on the first experiment (Chapter 2), negative and positive stimuli can have a marked effect in how a situation is perceived, as shown by QASA measures. Furthermore, in Chapter 6 it was shown that emotional stimuli, of both negative and positive valence, did have a detrimental effect in the processes of decision making, interrupting normal decision making performance, as was found in the same task without the emotional stimuli (Chapter 4). To extend the investigation further, a modified version of the bisection task to will be used in this chapter to investigate the cognitive mechanisms of the effects of emotional stimuli in decision-making.

There is an ongoing debate whether the decision made when target duration is perceived as more similar to the short referent or long referent in the bisection task is made with regard to the memory of the referents themselves or, conversely to a

decision criteria akin to that used in signal detection tasks (Allan 2002; see also Chapter 1 section 1.6.1). Earlier versions of the bisection tasks did not include the referents duration in every comparison trial. In other words, the referent durations were used to train the participants' memory, often termed as referent memory. Participants then, it was assumed, used the referent memory during the target presentation to make the comparison with the target duration so that a decision would be made whether the target interval was perceived to be closer to the longer or shorter referent. There is accumulating evidence, however, which suggest that the referent durations, rather than used as direct comparisons to the target stimuli, are used to establish a decision criterion against which target durations are measured and a decision is reached. The evidence, however, is conflicting and there is no broad agreement among researchers in this area.

For example, Rodriguez-Girones & Kacelnik (2001) run a modified version of the bisection task in which the referents were presented sequentially but varying in duration. Similar to the previous experiment (Chapter 8), the two referents durations were counterbalanced and presented on each trial before the target duration; the durations of the referents varied in each trial, known as the roving-referents bisection task. As opposed to the fixed referents version, in the roving-referent version, it was argued, the memory of the referents could not be established reliably since they were not constant. The results showed that the performance of the participants significantly deteriorated with the introduction of the roving-referents as opposed to the fixed referents. Rodriguez-Girones & Kacelnik argued the comparison of the target was made against the referents presented in each trial. In other words, the roving-referents prevented a reliable reference memory to be established in the long-term memory

hence suggesting that the participants compared the duration of the target to the referents in each trial.

However, in another modified version of the bisection task, Wearden & Ferrara (1995, 1996) found that the absence of the referents yielded the same performance. Wearden and Ferrara presented participants with a set of target intervals of varying durations. Participants were asked to simply partition the target durations into short and long ones; note the absence of the referents. They found that even in the absence of the referent durations, participants yielded similar data when the referents were present thus suggesting the comparison of the duration of the target intervals must be made against some criterion and not directly compared to the actual stored memories of the referent durations.

In a series of experiment, Allan (2002) supported the conclusion reached by Wearden and Ferrara and suggested that the referent durations used in training served to establish a decision criterion, that is to say, the target intervals were not compared to either referent but to a general decision criterion they help establish. Allan (2002) found that in fixed referent, roving referents and even when feedback for each trial was given, the data was similar hence, suggesting that the referents simply established a criterion after which the presentation of the referents did not have much effect. However, developmental differences have been found. For example, Droit-Volet & Rattat (2006) found that 5 and 8 year olds showed a lowered temporal sensitivity when the bisection task did not use referents (as in Wearden & Ferrara 1995, see above) compared to when referents were used; adults did not show a difference.

It is not known, however, whether timing of emotional stimuli are also processed in the same way with regard to the bisection task. The experiments above that support the idea that referent durations serve to form a decision criterion use

neutral stimuli in their experiments. However, both experiments, Chapters 7 and 8, and other experiments too (Droit-Volet, Fayolle & Gil, 2011; Schirmer 2011; Lambrechts, Mella, Pouthas. & Noulhiane 2011) show that affective stimuli are not processed in the same way as affectively neutral stimuli. Therefore, it is not known whether affective stimuli would be more likely to be processed with regard to the referent durations directly or to a decision criterion. The distinction is important because it implies the involvement of different memory processes. If the comparison takes the form of target against a decision criterion then that is more likely to involve the long term memory in the decision processes. Otherwise, if the comparison takes the form of target against the referents presented in each trial, then working memory is more likely used (Rodriguez-Girones & Kacelnik 2001). Furthermore, if a decision criterion is used, as opposed to trial referents, that indicates a lack of SA as, presumably, the given referent durations in each trial are not utilized.

In terms of affective involvement, the negative emotional stimuli are more likely to lead to the use of a decision criterion whereas for the positive one the trial referents. This would be in line with the findings of Chapter 2 where negative emotional valence was found to lead to a more focused SA than positive emotional valence. In other words, a negative affective valence that leads to a more focused processing of information is then more likely to ignore relevant information in the environment and use a rule of thumb or a decision criterion as a guide whereas a positive emotional valence that leads to a more distributed SA is then likely to result in the use of a wider range of information; hence it is more likely that the trial referents are utilized in decision making when they are available under the positive and neutral affective conditions and the decision criterion under the negative affective condition.

In the following experiment the bisection task was manipulated so that the decision on the perception of time intervals could be made either against a decision criterion or trial referents. Participants were trained with a set of referents using a different duration from the referents that were presented in each trial. The training referents had a duration of: short referent = 800ms, long referent = 1600ms. The trial referents were the same as the ones used in the previous experiment: short referent = 400ms, long referent = 1600ms; the target stimuli had a fixed duration of 1131ms.

This means that, if the decisions are made against the decision criterion established by the training referents, then it is more likely that more responses will be '*short*' rather than '*long*' since the target would be closer to the shorter referent than the longer referent by 138ms  $[(\text{long referent} - \text{target}) - (\text{short referent} - \text{target}) = (1600 - 1131) - (800 - 1131) = 138\text{ms}]$  – in other words the target is closer to the shorter referent by 138ms compared with the longer referent. Whereas, if the decision is made with regard to the trial referents, then the answers to the comparison of the duration of the target interval are more likely to be '*long*' since the target is closer to the longer referent by 262ms  $[(\text{long referent} - \text{target}) - (\text{short referent} - \text{target}) = (1600 - 1131) - (400 - 1131) = 262\text{ms}]$  – in other words the longer referent is 262ms closer to the target compared with the shorter referent). The hypothesis is that negative emotional stimuli will be judged against the decision criterion (established during training referents – hence more responses would be '*short*' for the negative stimuli) whereas positive emotional stimuli will be judged against the trial referents.

To summarize the above in simple words, the durations of the pair of the training referents and trial referents are different. The only difference is the training referents have the short referent 400ms longer. This is also the only major difference

compared with the preceding experiment. The rest of the structure of the experiment remains largely the same.

It should be noted that the positive stimuli is likely to yield more responses short regardless since the conditions have not changed to a significant degree from the previous experiment (Chapter 8). In the Chapter 8 experiment, it was found that target stimuli of positive valence with a duration of 1200ms and with trial referents of 400 and 1600ms durations did yield significantly more responses short than long. It is not expected that dropping the target from 1200 to 1131 would result in any significant differences, if anything, there would be more responses short. The most interesting possibility is whether the negative stimuli, which was found to be perceived as mostly long in the previous experiment, were perceived to be as mostly short – which is to say, perceived to be closer to the shorter referent. If this were the case, there would be strong support for the idea that the processing of the emotionally negative stimuli mainly involves information from long term memory stores to the cost of ignoring some of the possibly relevant perceptual information held in working memory.

## 9.2 EXPERIMENT 7 – INVESTIGATION THE PROCESSES OF DECISION MAKING IN TIME PERCEPTION

### *9.2.1 Method*

#### *9.2.1.1 Participants*

Ten participants were randomly selected (opportunity sampling) mainly from students of the first, second and third year of the psychology course at the University of Gloucestershire (mean age = 31.70, SD = 11.81, 3 female, 8 right handed).

### *9.2.1.2 Materials*

#### *Stimulus Presentation Computer*

The same stimulus computer was used as in other experiments.

#### *Apparatus*

Each session involved the administration of a computerised Time Estimation task, provided by the experimenter (see section 9.2.1.3 below for more details). Sessions took approximately 40 to 45 minutes.

#### *Spielberg State Anxiety Inventory*

The same questionnaire as used in experiment 1.

#### *International Affective Picture System images (IAPS)*

Based on the normative ratings of arousal for males and females separately, the images were distributed so that the arousal values did not differ significantly between the affective conditions of positive and negative and within and between male and female sets (table 9.1).

#### **IAPS images Female Sets**

1. *Positive Set* ( $n = 30$ ): 1710, 2347, 2150, 2165, 5833, 2058, 2045, 5910, 8190, 7330, 1811, 2209, 8470, 8420, 8200, 8370, 4626, 8185, 8080, 4614, 8499, 8501, 4525, 4640, 4575, 2208, 4542, 4660, 8034, 5629.

2. *Neutral Set (n = 30)*: 7490, 7026, 5740, 7187, 7052, 7100, 7950, 7035, 7004, 7080, 7185, 7000, 7041, 5471, 7217, 7175, 7020, 2397, 7010, 2190, 2840, 7059, 7031, 7491, 7705, 7150, 7110, 5130, 7060, 9360.
3. *Negative Set (n = 30)*: 9421, 2800, 9140, 9420, 9301, 9326, 9435, 3350, 3103, 9185, 3191, 3180, 3230, 3225, 2205, 9325, 9253, 3016, 9405, 2703, 9921, 6563, 2095, 3059, 3131, 9433, 3015, 3168, 9075, 3068.

#### **IAPS images Male Sets**

1. *Positive Set (n = 30)*: 4250, 4210, 4180, 5833, 8501, 8190, 5825, 1710, 1440, 1750, 4220, 4150, 1460, 4008, 4680, 5700, 8170, 8370, 4660, 8510, 4225, 4310, 4142, 8499, 4668, 8185, 4001, 4697, 8179, 4770.
2. *Neutral Set (n = 30)*: 7165, 7140, 7052, 5471, 7080, 7026, 7100, 5740, 7020, 7233, 7041, 7009, 7090, 7010, 7000, 2840, 7004, 7187, 7185, 7035, 7175, 7705, 7040, 7217, 7950, 7110, 7025, 7224, 5130, 7031.
3. *Negative Set (n = 30)*: 9252, 3500, 3068, 3059, 6313, 6350, 3030, 6570, 9413, 3140, 3010, 6563, 3069, 3110, 3001, 3530, 3071, 9183, 9410, 3060, 9940, 3130, 3100, 3120, 3170, 3000, 3131, 3080, 3102, 3053

	Female		Male	
	Valence (mean/sd)	Arousal (mean/sd)	Valence (mean/sd)	Arousal (mean/sd)
Positive	7.86 / .35	5.95 / .56	7.71 / .40	6.42 / .91
Negative	1.6 / .20	6.13 / .60	2.06 / .29	6.48 / .41
Neutral	4.96 / .32	2.47 / .26	4.93 / .38	2.47 / .53

*Table 9.1: The Valence and Arousal Means and Standard Deviations for All Affective Conditions – scale 1 to 9, 1 low arousal/ negative valence, 9 high arousal/positive valence. The normative valence and arousal means and standard deviations for the images of each affective condition, positive, negative and neutral, are shown separately for males and females. Note, the arousal values for the positive and negative group are roughly similar, whereas the valence values are markedly different.*

### 9.2.1.2 Design

The main part of this study utilises a repeated measures design with one independent variable, the affective condition with 3 levels, positive, negative and neutral and taking as DV the difference between the responses “long” with the responses “short” so that a negative number indicates a contraction of time perception and a positive number a dilation of time perception.

The task has 90 trials overall. To assess the perception of time intervals and arousal and valence levels associated with each image presented in each trial, four questions were asked at the end of each image presentation assessing the perceived duration of the image, confidence in that judgment, and valence and arousal ratings for each IAPS image.

Furthermore, the task was manipulated so that, unbeknown to the participants, the duration of the referents presented in training was different from the duration of the referents presented in each trial (see procedure for more detail). It is expected that the duration of the affectively negative stimuli will be judged relative to the referents during training whereas the duration of the neutral and positive stimuli will be judged relative to the referents presented in each trial thus showing that the processes

involved in decisions that have a negative emotive aspect differ from those of decisions that are affectively neutral and positive.

### *9.2.1.3 Procedure*

After giving informed consent, participants were led into a softly lit room and asked to sit in a reclining chair. The test itself was presented entirely on the computer screen and the experimenter was absent throughout the duration of the task. Participants were asked to follow instruction from the computer screen. While the experiment was running, the experimenter was located in an adjacent room. Upon finishing the task, participants were instructed to ring a bell to notify the experimenter.

Participants were required to judge whether the duration of an image on screen, following two referent durations, one 400ms, one 1600ms, was closer to the longer duration image or the shorter one. Prior to these, participants were trained to distinguish between two referents, one 800ms long, the other 1600ms long.

#### *Step 1 – Participants anxiety was measured*

The same procedure was followed as in the previous experiment.

#### *Step 2 – Participants were trained to distinguish between a short and long duration (Referents)*

The procedure was the same as in the previous experiment with only one difference, the short referent had a duration of 800ms as opposed to 400ms in the previous experiment. Please note that during the trials when participants were required to make a duration judgment, the duration of the short referent, without the participants knowing, it was changed to 400 milliseconds (see step 6).

*Step 3 – Participants were asked to distinguish between short and long duration Referents*

Next participants were asked to actively distinguish whether the same, randomly presented durations of 800 and 1600ms were LongD or ShortD. Feedback was given after each attempt. At the end of this step, participants were asked to continue only if they felt confident they could distinguish between these two durations comfortably – all participants were able to comfortably distinguish between the durations.

*Step 4 – Instructions for the rating procedures were given*

Next participants were presented with the standard instructions for IAPS rating procedures for Valence and Arousal respectively (see IAPS technical manual, Lang, Bradley & Cuthbert, 2008, for a full).

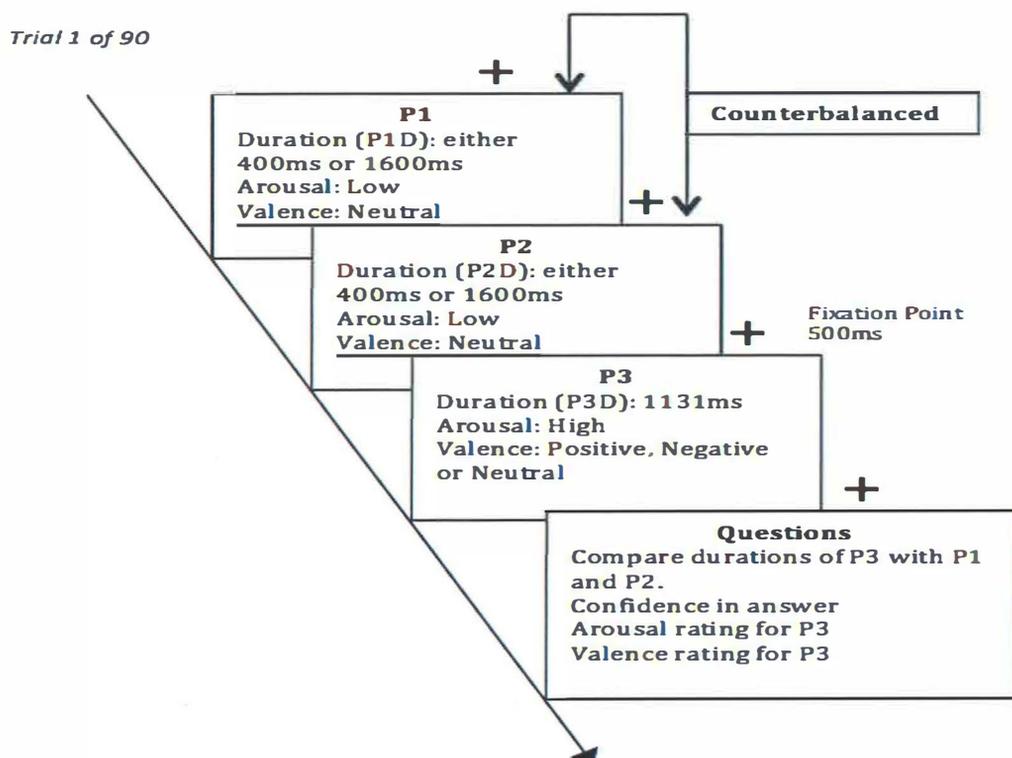
*Step 5 – Main task instructions*

Next participants were given the instructions for the main task.

*Step 6 – Participants were required to judge whether a time interval of a positive, negative or neutral image presented on screen, was closer to the longer or shorter Referent.*

The main experiment started. Participants saw a fixation cross which stayed on screen for 500ms, followed by the same image encountered during training (Steps 2 and 3) with randomly but counterbalanced alternating durations of 400 (note, this was different from the training session – see steps 2 and 3) or 1600ms, followed by a fixation cross followed by the other duration than the one just previously presented

followed by a fixation cross, followed by one of the IAPS images randomly selected from one of the Sets. The IAPS image stayed on screen for 1131 milliseconds. The participants answered some questions at the end of each trial (Figure 9.1).



*Figure 9.1: Main experiment structure.*

*Step 7 - Participants anxiety was measured again*

Participants were asked to complete again the on-line version of State Anxiety Inventory (SAI) (Spielberger, 1989).

## 9.2.2 Results

### 9.2.2.1 STAI Control Results for Genders

To assess whether any of the affective conditions had a stronger effect in participants, state anxiety scores were collected before and after presentation of emotional stimuli. If the anxiety scores increased, that would indicate that negative images had the stronger effect, if anxiety scores decreased, the positive images had the stronger effect, else the data would suggest that the negative and positive images had an equal effect in participants' anxiety, effectively, cancelling each other out.

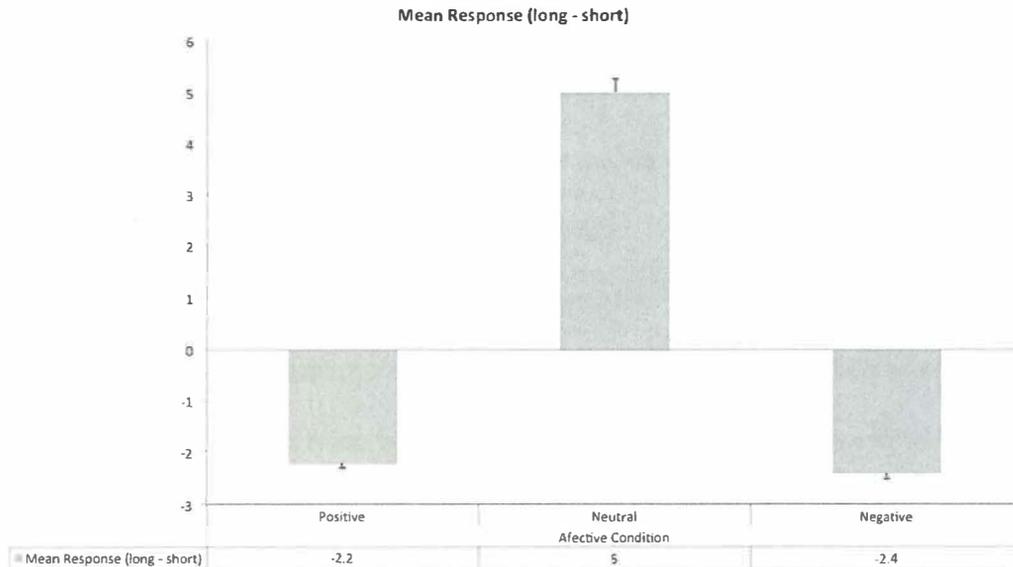
A paired-samples t-test was used to elucidate whether there was a statistically significant mean difference between the anxiety scores before the exposure to affective stimuli compared to after. No outliers were detected and the assumption of normality was not violated, as assessed by Shapiro-Wilk test ( $p > 0.05$ ). No significant difference was detected thus confirming that neither the positive nor the negative images had stronger effect on participants.

### 9.2.2.2 Results of Time Perception

The Bisection scores were calculated by subtracting the number of responses "short" from responses "long". Hence a negative number indicates a higher proportion of "short" responses – contraction of time perception - a positive number a higher proportion of "long" responses – dilation of time perception; zero means equal number of "long" and "short" responses.

Below are the means table along with the bar chart of the responses (Graph 9.1). It can be seen from the graph that both the positive and the negative affective

conditions show a tendency to lead to a contraction of the time perception, and in a similar level, contrary to the neutral condition.



*Graph 9.1: Mean of Bisection Scores for All Affective Conditions (CI 95 %). Both the positive and negative emotional stimuli are perceived as shorter than the neutral stimuli.*

A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in the perception of time over the different affective conditions. There were no outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ( $p < .05$ ), respectively. The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). The affective condition elicited statistically significant changes in the perception of time,  $F(2, 18) = 4.75$ ,  $p < 0.03$ ,  $\eta^2 = .35$ , with the perception of time decreasing from neutral (mean = 5.00, SD = 10.21) to positive (mean = -2.20, SD = 9.02) and to negative (mean = -2.4, SD = 12.21). *Post-hoc* analysis with a Bonferroni adjustment did not reveal significance differences among the groups.

The results from time perception scores show that the affective condition significantly affected the perception of time, as assessed by ANOVA. The mean scores indicate that both the negative and positive affective conditions were associated with a contraction of the perception of time whereas the neutral affective condition with a relative dilation. Considering that in the previous experiment the responses for the negative images was mainly long (see Graph 8.1 at 1200 millisecond), the results here suggests that the negative affective stimuli was considered with regard to the training referents (long term memory) to make the decision whereas that neutral and positive affective conditions utilized the immediate referents (working memory) thus confirming the experimental hypothesis.

#### *9.2.2.2 Results of Confidence Measures*

The responses of participants were calculated by adding them up so a higher score would indicate higher confidence in answers and lower score, lower confidence.

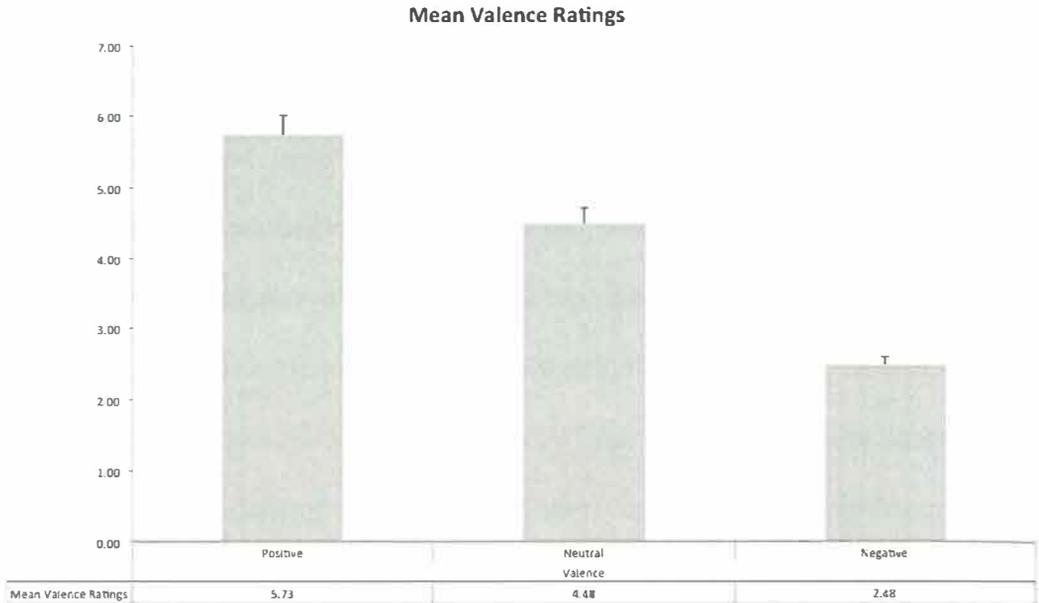
A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in confidence ratings over the different affective conditions. There were no outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ( $p < 0.05$ ), respectively. The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). The affective condition did not elicit statistically significant changes in confidence ratings.

#### *9.3.5 Results of Valence Measures*

The responses of participants were calculated by adding them up, averaged then rescaled so that a score of 9 would mean highly pleasurable whereas a score of one would mean extremely disagreeable.

Below are the means table along with the bar chart of the responses (Graph 9.2). The means show, as expected, that the negative images have a lower value on the valence scores, the neutral is in the middle and the positive images are perceived as the most pleasurable.

A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in the valence ratings over the different affective conditions. There was one outlier in the positive condition as assessed by boxplot. The outlier was replaced with a value closest to it. The data was normally distributed for the negative and positive group but not for the neutral group as assessed by Shapiro-Wilk test ( $p < 0.05$ ) and ( $p > 0.05$ ), respectively. The assumption of sphericity was approaching violation, as assessed by Mauchly's Test of Sphericity ( $p = 0.05$ ). Therefore, a Greenhouse-Geisser correction was applied ( $\epsilon = 0.66$ ). The affective conditions did elicit statistically significant changes in the valence ratings  $F(1.31, 11.80) = 61.84, p < 0.01, \eta^2 = .87$ , with the valence ratings increasing from negative  $2.48 \pm 1.28$  to neutral  $4.48 \pm 0.67$  and to positive  $5.73 \pm 0.50$  (Graph 9.2). *Post-hoc* analysis with a Bonferroni adjustment revealed that the valence ratings were statistically significantly increased from negative to neutral (2.00 (95% CI, 1.15 to 2.85), increased significantly from neutral to positive (1.24 (95% CI, 0.71 to 1.78) and also increased significantly from negative to positive affective condition (3.24 (95% CI, 2.14 to 4.35) thus confirming that the images had the expected effect on the participants with the negative images having the strongest effect.



Graph 9.2: *Mean of Valence Scores for All Affective Conditions (CI 95 %)*. The valence ratings increase from to negative to neutral and to positive as expected.

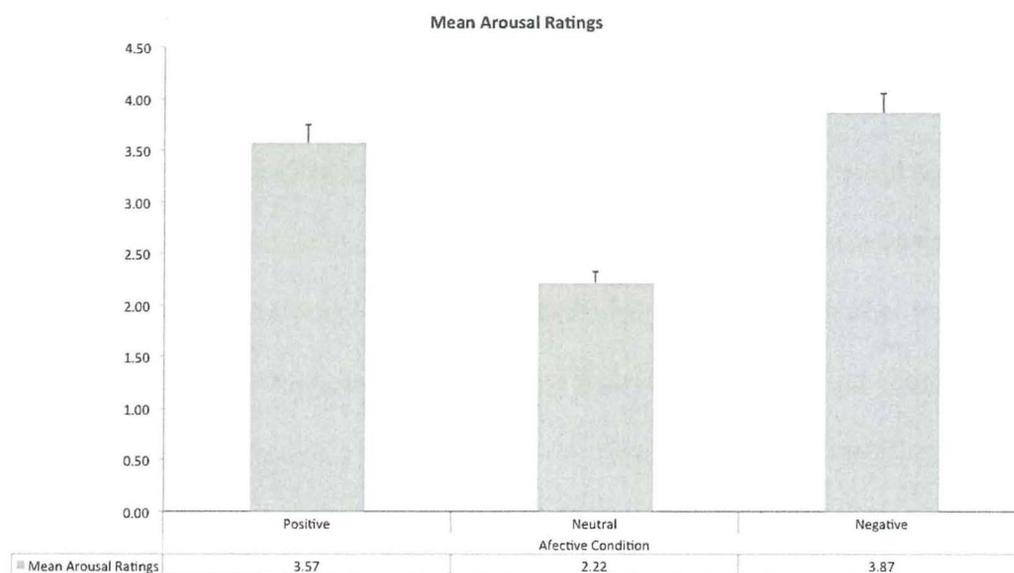
### 9.2.2.3 Arousal Measures

The responses of participants were calculated by adding them up and averaged so that a score of 9 would mean high arousal whereas a score of one would mean low arousal.

Below are the means table along with the bar chart of the responses. (Graph 9.6). As expected, the graph shows that the positive and negative images are perceived as equally high arousing compared to the neutral images.

A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in the arousal ratings over the different affective conditions. There were no outliers as assessed by boxplot. The data was normally distributed for the negative and positive group but not for the neutral group as assessed by Shapiro-Wilk test ( $p < 0.05$ ) and ( $p < 0.05$ ), respectively. The assumption of sphericity was not violated, as assessed by Mauchly's Test of Sphericity ( $p > 0.05$ ). The affective conditions did elicit statistically significant changes in the arousal

ratings  $F(2, 18) = 5.18, p < 0.02, \eta^2 = 0.37$ , with the arousal ratings increasing from neutral  $2.22 \pm 1.63$  to positive  $3.57 \pm 1.31$  and to negative  $3.87 \pm 2.19$  in that order. *Post-hoc* analysis with a Bonferroni adjustment revealed that the arousal ratings were statistically significantly increased from neutral to positive (1.36 (95% CI, 0.10 to 2.61),  $p < 0.04$ ). No other differences were found thus confirming that the positive images had the strongest effect in the participants' arousal levels.



*Graph 9.3: Mean of Arousal Scores for All Affective Conditions (CI 95 %).* The arousal scores increase from neutral to positive and to negative. The negative and positive arousal scores are similar whereas the neutral score is noticeably lower.

### 9.3 DISCUSSION

Before discussing the main finding, the results from the control measures will be discussed. The state anxiety score taken for before and after the presentation of affective stimuli showed that there were no differences in the participants anxiety levels by the exposure to the emotionally mixed stimuli. The explanation could be that emotionally positive and negative stimuli cancelled out their respective effects on the participants' anxiety levels. Even though no differences are detected on the

anxiety levels, other, individual measures of the participants' perception of the affective stimuli show that, indeed, participants were affected by the emotional stimuli as expected.

The measure of the valence associated with each image presented showed that negatively valenced images were perceived as significantly more negative than neutral images. Also, and as expected, the positively valenced stimuli were perceived as significantly more pleasurable than the neutral stimuli thus confirming that the IAPS images had the desired effect in the participants' perception of the images. The arousal scores also showed a significant difference, especially the positive images were perceived as significantly more arousing than the neutral stimuli. The important finding here is that no significant differences in arousal between the negative and positive emotional stimuli were found, suggesting, therefore, that only the valence changed significantly between the two.

The main finding of this experiment, however, is that negative emotional stimuli appears to be judged against the decision criteria formed by the referents during training whereas the positive and neutral stimuli appear to be judged against the trial referents thus confirming the experimental hypothesis. This conclusion is better understood in conjunction with the findings from the previous experiment. The training referents and the trial referents in the previous experiment were the same and, furthermore, they were also the same with the trial referents in this experiment. The only variable that changed was the training referents on this experiment; the short referent was set from 400 in the previous experiment to 800ms in this experiment. The only change observed on the participants' behaviour was that negative images were perceived as being shorter, whereas neutral and positive images were perceived roughly the same as in the previous experiment. In other words, lengthening the

duration of the “*short*” training referent to 800ms, but keeping everything else the same led to participants experiencing the duration of the negative images as shorter. This is despite the fact that a comparison against the referents displayed in every trial, arguably, would have led to the negative images being perceived as longer. Therefore, the likely explanation is that the negative stimuli were being compared against the training referents and not the trial referents. Almost Freudian in scope, it suggests that negative stimuli specifically may be more reliant for their processing on long-term memory whereas positive and neutral stimuli appear to be more reliant on working memory structures. The remarkable finding to note here is that, both, the positive and the neutral stimuli hardly changed at all from the findings in the previous experiment, it is the negative stimuli alone which shows a substantial change in the experience of time thus supporting the conclusion that only the negative stimuli are affected by the manipulation of the training referents.

The finding here suggest, in line with the QASA analysis (see Chapter 2) and other studies (Mather et al., 2006; Hulse & Memon, 2006, 2007; Kohn, 1954) that negative stimuli may lead to a focused type SA and that furthermore, in these circumstances, the data here suggests, the decisions made tend to rely more on previous information residing in the long-term memory store with the trade off that some of the available information, which could be helpful in improving performance accuracy, is ignored.

## Chapter 10 - Summary and Conclusions

### 10.1 INTRODUCTION

In this part of the thesis each chapter will be summarised and the main themes and findings will be outlined. The order of the chapters, as presented thus far, will be generally maintained. The summary of each chapter will identify and outline the general themes of the arguments as well as the main conclusions. Where original contributions to the disciplines studied are claimed, they will be highlighted and the original aspects will be described. This section, however, does not aim to expound upon different points with exhaustive detail but merely point out general themes and when reasonable, focus briefly on specific details. This section will also be used to highlight some of the limitations of the experiments, the reasons for those limitations and attempts made to overcome them. One persistent limitation of most of the studies presented in this thesis is the number of participants, especially for experiments in chapters 4 and 9. Despite many attempts in many different forms (leaflets around the university and the town, request for assistance from staff at the University of Gloucestershire as well as friends and family, recruitment attempts in various social media outlets, such as Facebook), the recruitment of participants remained one of the more difficult challenges. However, once this difficulty became clearer, the design of the experiments was tailored so that fewer participants were required to achieve reasonable statistical power. As can be seen from most experiments, a within subjects design was used when possible, which requires fewer participants to achieve reasonable power. Furthermore, since the main problem when using small samples in statistical analysis is the increased probability of a, so called, type 2 error (failure to reject a false null hypothesis), then the experiments presented here, especially those in

chapters 4 and 9, were of sufficient power since an effect was detected and the experimental hypothesis confirmed. The other problem with the small samples is that they are less representative of the population. As highlighted above, various attempts to increase the number of participants were made and most experiments have a reasonable sample size. It is important, however, to acknowledge that more participants would have generally been an improvement.

## 10.2 CHAPTERS GENERAL SUMMARY

### *10.2.1 Chapter 1*

Chapter one focused on investigating the main models of SA as well as the current state of research in this area. A critical evaluation of the available literature identified several shortcomings of the current dominant models. Furthermore, an argument was made that the understanding of SA could be taken further by integrating emerging knowledge from related fields of research, especially the cognitive neuroscience of decision-making and emotions. A particular model of SA, QASA, was identified as the most promising to investigate SA within the context of emotional processes. The theme emerging from Chapter one was brought into a more detailed focus and subsequently led to the first experiment, which tested the QASA measures of SA under different affective conditions.

### *10.2.2 Chapter 2*

The effects of negative and positive affect on memory and attentional processes, which are fundamental processes of cognition therefore also fundamentally connected to the processes supporting SA, were explored. Based on the review, it was

hypothesized that negative and positive affect would lead to a more stringent or relaxed criteria, respectively, for filtering information. A novel paradigm for testing this hypothesis was designed to control for the effects of different affective conditions. It was found that positive and negative affective conditions had highly predictable and somewhat opposing effects on SA, Information Bias and, importantly, to their relationship, as shown by the QASA measures. In other words, analysis of the data suggested that negative affective conditions were related to a narrower information bias (participants appear to have a more stringent criteria on accepting information as true) and, conversely, that positive affective conditions were related to a more relaxed information bias (the criteria for accepting information as true was less stringent). The investigation and the finding that different affective conditions have different effects on the processes of SA is, as far as the author is aware, a new contribution to the field.

Having found that emotions have an effect on the processes of SA, the next chapter was focused more on the emotional effects in another important aspect of SA, that of decision-making.

### *10.2.3 Chapter 3*

Following from the evidence that emotions are involved in the processes of SA, as suggested by the experiment in Chapter 2, Chapter 3 was therefore focused on the current state of research on emotions. Since an important aspect of SA is its relationship to decision-making processes, the emotional research on cognitive psychology and neuroscience was explored within the context of decision-making.

Both, neuroscience and cognitive theories suggested the existence of two separate systems (system I and system II, or channel and global functioning), underpinned by different but overlapping neural systems and serving different

cognitive functions. The Somatic Marker Hypothesis (SMH) was identified as a model, which attempted to integrate evidence from both fields, neuroscience and cognition, and presented a plausible and easily tested model of decision making. Importantly, SMH accounted for the influence of emotions on the processes of learning and decision-making and was based on a widely validated tool, Iowa Gambling Task. The SMH suggests that embodied and largely implicit emotional factors associated with previous experiences are important for the processes of decision making. The argument was made that information bias (IB) and SM may be two sides of the same coin, first from the cognitive perspective and largely in line with operations of System I, and second from the neuroscience perspective, both essentially aiding decision making by determining the characteristics of the decision space.

Previous research on SM identified the pre-frontal cortex and the somatosensory cortex as important mediators of emotional influences on decision-making processes. This suggested that, a modified version of the Iowa Gambling Task could be used to investigate the neural correlates of IGT as reflected by EEG recording. The next chapter tested this proposition.

#### *10.2.4 Chapter 4*

Chapter 4 focused even further in investigating the influences of Somatic Markers in decision making under conditions where the situational factors that contribute to the creation of the Somatic Markers suddenly shift so that previously created Somatic Markers may hinder learning. This would allow for the detection of EEG correlates of emotional influences when learning takes place and when it does not.

The alpha EEG correlates on the frontal electrodes were recorded and analysed for before and after category change. It was found that at 400 to 300 milliseconds prior to a decision being enacted, the frontal electrodes, especially the mid-frontal electrodes (electrode FZ according to the international 10/20 system), was able to distinguish between the advantageous and disadvantageous responses for pre-category change but was absent after the category change. It was suggested that the SM400 found at the frontal electrodes in the alpha frequency may be reflecting the Somatic Markers since they were detected only under conditions when learning had taken place. More research and independent verification is, of course, needed, however, as far as the author is aware this is also a new finding in this area of research.

#### *10.2.5 Chapter 5*

Chapter 5 investigated the possibility that SM400 may simply reflect stimulus-response association learning. It was argued that there is a crucial distinction between the stimulus-response association learning and the Somatic Marker theory of learning. Stimulus-response association learning, it was argued, was based on the immediate feedback/consequences of actions, which then conditioned the behaviour in one way or another, driven towards behaviours that are rewarding and away from the ones that are punishing. The Somatic Markers were, instead, sensitive to long-term outcome of actions. To test this, the IGT task was modified to dissociate the long-term feedback from the immediate choices, in the sense that the long-term outcomes did not accurately reflect the punishment schedules of the choices. The data showed that under these conditions, participants did not learn the task and this was also reflected by the absence of the SM400 EEG signal. It was suggested that since the manipulation of the long-term feedback led to the task not being learned and the

absence of the SM400, then the learning in the IGT task may be more in line with the SMH explanation as opposed to stimulus response association learning. In other words, a malfunctioning of the systems evaluating the long-term consequences hinders learning.

### *10.2.6 Chapter 6*

In Chapter 6, a further possibility was ruled out; that the observed behaviour of the participants performing in the IGT might be driven by anticipatory anxiety and that that is reflected by the SM400 EEG marker. Prior research indicated that anticipatory anxiety shares many cognitive and neural circuits with the operation of Somatic Markers. Aside from the overlaps, the distinction between the systems, it was argued, was that while the anticipatory anxiety might also drive behaviour in the same way as Somatic Markers, away from the risky choices and towards the safe ones, it does not lead to the same type learning and it is more susceptible to individual differences than Somatic Markers. In other words, anticipatory anxiety may be a more general tendency of generally anxious people to avoid any risky behaviour as opposed to having a feeling about which decision is more advantageous in the long run, which is what Somatic Markers represent. The Iowa Gambling Task was modified to control more explicitly for conditions of anticipatory anxiety and the behavioural and EEG data were examined to see whether the learning reflected this and whether SM400 also reflected anticipatory anxiety. The IGT was tested in incongruent-congruent (negative stimuli was initially, in phase 1, paired with the safe decks and then with the risky decks) and congruent-incongruent (negative stimuli was initially, in phase 1, paired with the risky decks and then with the safe decks) conditions. It was found that, in both conditions, the introduction of anxiety provoking stimuli did not lead to the

participants learning the task and that this was also reflected by the absence of the SM400. This suggested that SM400 does not reflect anticipatory anxiety and that learning in the IGT is unlikely to be driven by anticipatory anxiety.

### *10.2.7 Chapter 7*

Following on the findings from Chapters 2 to 6 which suggested, generally, that different emotions had different effects in SA and decision making, chapters 7 and onwards focused further still on investigating the mechanisms by which emotional stimuli affected learning, SA and decision-making. A vastly understudied subject, the relationship between the perception of time and different emotional states was identified as a possible way to explore the cognitive mechanisms through which emotional processing affects learning, SA and decision making. It was found that the valence of emotional arousal affects, or is affected by, the variations in the time perception. The data did suggest that negative images did induce a dilation of time perception and positive images a contraction relative to the neutral images with the negative images showing the largest effect in distorting time perception. Furthermore, the results also supported the finding in the first experiment (Chapter 2), that negative affective condition is associated with reduced SA.

### *10.2.8 Chapter 8*

Following from Chapter 7, which investigated the timing mechanisms under different affective conditions for 2 to 9 seconds range, Chapter 8 was focused in the time intervals around the 1-second. Research around this particular interval suggested that neural systems supporting the sub and supra-second time intervals, different in

each case, converged around the 1-second interval. The experiment in this chapter tested testing f sub (under 1000 ms) and supra-second (over 1000ms) interval timing in conditions of negative, positive and neutral affective conditions. Due to the additional involvement of the brain areas processing emotion, it was predicted that, in particular, supra-second timing will show that negative images will slow down the perception of time and positive images speed it up relative to the neutral images, the same as was found in the previous experiment. It was found that high negative arousal at sub-second intervals (600ms) had a strong effect and dilated the perception of time whereas high positive arousal at supra second intervals (1200ms) had also a strong effect and contracted the perception of time. It was argued that negative affective stimuli are preferentially processed at short intervals since, for example, if they indicated real danger, it would be evolutionary adaptive to notice and avoid any potential harm first. Positive stimuli, on the other hand, is also important to process because getting to the rewards (i.e. food, a mating partner) is also evolutionary important but it does not have the same urgency as avoiding a potential harm.

### 10.2.9 Chapter 9

Chapter 9 investigated the possibility that the operations of the timing processes under different affective conditions might be used to show the mechanisms by which different affects, especially negative affect, influence the processes of memory and decision making. Given the results from the previous experiment (Chapter 8) the bisection paradigm was designed to manipulated one aspect of the “*long-term*” memory, the short referent on the bisection task, so that it was longer during referent training, but shorter during the main task. It was found that the negative affect alone was influenced. While the neutral and positive affective

condition yielded roughly the same behavioural pattern as observed in Chapter 8, negative affect on the other hand showed a complete reversal of the observed behaviour. It was argued that the evidence from this experiment supports a separation so that the timing processes involved in the negative affect are mainly based on the long-term memory whereas the those involved in the neutral and positive affect use working memory, hence suggesting a possible mechanism by which the effects that negative and positive affective condition on memory and decision making may be explained.

### 10.3 – ORIGINAL CONTRIBUTIONS TO RESEARCH AND FURTHER RESEARCH

Lastly, I would like to finish this thesis by presenting a short list of the findings, which I hope have at a modest degree provided original contributions to research:

1. *Chapter 2: It showed that different affective conditions may affect the processes of SA differently.*
2. *Chapter 4: It was shown that an Alpha EEG signal (SM400) on the frontal electrodes was capable of distinguishing between the decisions which were advantageous and those which were disadvantageous even when such information was not available in the conscious awareness.*
3. *Chapter 5: It was shown that SM400 was not likely to reflect an emotional signal reflecting immediate, stimulus-response consequences.*
4. *Chapter 6: It was shown that SM400 was not likely to reflect anticipatory anxiety.*
5. *Chapter 9: It was shown that negative affective stimuli are likely to rely more on the long-term memory than positive and neutral affective stimuli.*

As regard the Situation Awareness, the experiments in this thesis have highlighted and shown that the removal of emotional influences from any model that attempts to measure SA greatly hinders them. Negative and Positive emotional influences appear to have distinctive effects on the processes of attention, decision- making and the perception of time, all of which are important aspects of any current or would be SA model.

Finally, one of the most intriguing results to the author is the one found in Chapter 9, which suggests separate cognitive processes supporting the processing of different affective stimuli. Given more time and space in this thesis, a modified version of the task in Chapter 9 manipulating the "long" referent (as opposed to the short referent) would have been conducted. If that had led to the positive affective condition reflecting the manipulation, than this would have been strong support for the separation of the processes supporting different affective stimuli. It is hoped that the work presented here would enable me to continue and hopefully further advance this line of research.

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## **APPENDIX**

## APPENDIX A

### *DATA Screening and Raw Analysis*

#### INTRODUCTION

Below are outlined a representative sample of the raw data screening and analysis for each main section. Where appropriate, the data are analysed in the following general order, Data Screening, Main Analysis, Post-Hoc Tests:

##### 1) Data Screening and Assumptions

###### *1 Checking for Outliers*

Boxplots are a popular method for detecting outliers, which is readily available in SPSS explore procedure. Outliers are identified as data points that are 1.5 box-lengths from the edge (Tukey, 1977). Outliers are denoted with circular dots or asterisk (extreme outliers) with their case number labeled.

###### *2 Tests for Normality*

Checks were made whether the data were normally distributed using the Shapiro-Wilk test, which is recommended for small sample sizes (Shapiro & Wilk, 1965; Razali & Wah, 2011).

###### *3 Normalizing Outliers*

If outliers were detected, the first consideration was to inspect the data for entry errors (e.g. typed in the wrong key) or measurement errors (malfunction of equipment or out of range values). If, however, the data inspection suggested that the data points were genuine, it was decided to either 1) keep but normalize the outliers or 2) run an equivalent non-parametric test that is less sensitive to outliers.

If it was decided to keep the outliers (the outliers were present only on some levels and were not too numerous) then outliers were normalised to their nearest neighbor not an outlier, which, essentially, reduces the standard error and stabilizes the averages (Barnet & Lewis, 1978).

If it was decided that outliers were too numerous, present in most levels of IV and the data were not normally distributed in most levels of the IV, then a non-parametric test was run instead. There are no strict and widely agreed guidelines for this so each data set was judged separately.

A third option was to remove the outliers completely however this was ruled out due to the small number of participants the reduction of which would have led to a further reduction in power.

###### *4 Checking for Outliers again*

###### *5 Checking Homogeneity of Variances (or sphericity)*

If there was homogeneity of variances (or sphericity for within participants designs), no further

modifications were applied. If there was no homogeneity of variances or sphericity, Welch ANOVA (Moder, 2010) or Greenhouse-Geisser correction was applied to the data (Greenhouse & Geisser, 1959), respectively. In addition the results from the Games-Howell *post-hoc* test were used for multiple comparisons (Games & Howell, 1976) when assumptions were not met otherwise Tukey's Honestly Significant Difference (Abdi & Williams, 2010).

## 2) Data Main Analysis

This consisted mainly of ANOVAs, ANOVAs with Greenhouse-Geisser correction, Welch's ANOVA or a non-parametric equivalent depending on the type of analysis. If an interaction was found then the interaction was explored further in post-hoc tests, the main effects were ignored. Otherwise, if the interaction was not significant, then the main effects were explored further.

## 3) Post-Hoc Analysis

### 6 *Post Hoc Analysis*

Post Hoc tests were run whenever a significant interaction was found. Appropriate corrections were used for multiple comparisons (Bonferroni, Games-Howell, Tukey's HSD etc) as required for each test.

### 6. *Summary*

The data from every chapter went through the above general steps. An example of the data analysis is given below. The tables and graphs in each chapter below will be given the same heading as the analysis under which they appear in the main text. The intention is that the tables and graphs presented here aid the understanding of the analysis reported in the main text. Aspects of the data screening and analysis from Chapter 2, 4 and 7, which apply to the analysis of the data from the other experiments, will be presented in detail.

## *Original Raw Data Links*

All the original data files are found in the attached CD-ROM in SPSS (.sav) and tab delimited (.csv) formats. Below are the links to the SPSS files; the data in other formats can also be found in the same folder. The data files are in the original and normalised form (outliers normalised). Below are the links to the raw data files:

- 1) **CD-ROM/Appendix/Data/Chapter 2/QASA Original Data.**
- 2) **CD-ROM/Appendix/Data/Chapter 4/ Chapter IV Behavioural Data**
- 3) **CD-ROM/Appendix/Data/Chapter4/ Chapter IV EEG Data**
- 4) **CD-ROM/Appendix/Data/Chapter4/ Chapter IV Subjective Data**
- 5) **CD-ROM/Appendix/Data/Chapter 5/Chapter V Behavioural Data**
- 6) **CD-ROM/Appendix/Data/Chapter 5 Chapter V Subjective Data**
- 7) **CD-ROM/Appendix/Data/Chapter 5/Chapter V EEG Data**
- 8) **CD-ROM/Appendix/Data/Chapter 6/Chapter VI Subjective Data**
- 9) **CD-ROM/Appendix/Data/Chapter 6/Incongruent/ Chapter VI Incongruent**
- 10) **CD-ROM/Appendix/Data/Chapter 6/Incongruent Chapter VI Incongruent EEG**
- 11) **CD-ROM/Appendix/Data/Chapter 6/Congruent/Chapter VI Congruent**
- 12) **CD-ROM/Appendix/Data/Chapter 6/Congruent/Chapter VI Congruent EEG**
- 13) **CD-ROM/Appendix/Data/Chapter 7/ Chapter 7 Data**
- 14) **CD-ROM/Appendix/Data/Chapter 8/ Chapter VIII Data**
- 15) **CD-ROM/Appendix/Data/Chapter 8/Chapter VIII IAPS Data**
- 16) **CD-ROM/Appendix/Data/Chapter 9/ Chapter IX Data**
- 17) **CD-ROM/Appendix/Data/Chapter 9/ Chapter IX IAPS Data**

CHAPTER 2

2.2.2.1 Changes in Induced Affect

Test of Normality

Tests of Normality

Group		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Diff_Anxiety	Positive	.108	15	.200	.954	15	.594
	Neutral	.144	15	.200	.943	15	.424
	Negative	.141	15	.200	.969	15	.844

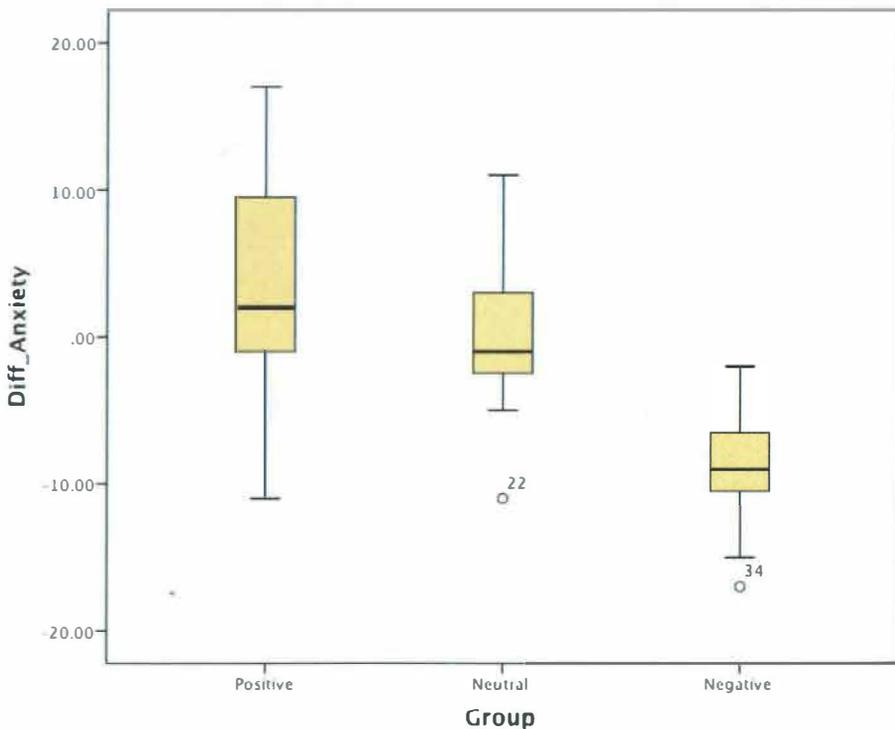
\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Shapiro, S. S. & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika*, 52 (3-4), 591-611.

Razali N.M., & Wah Y.B. (2011) Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. *J. Stat. Model. Anal.* 2(1), 21-33.

Checking for Outliers



Tukey, J. W. (1977). *Exploratory Data Analysis*. Addison-Wesley.

### Testing Normality Again

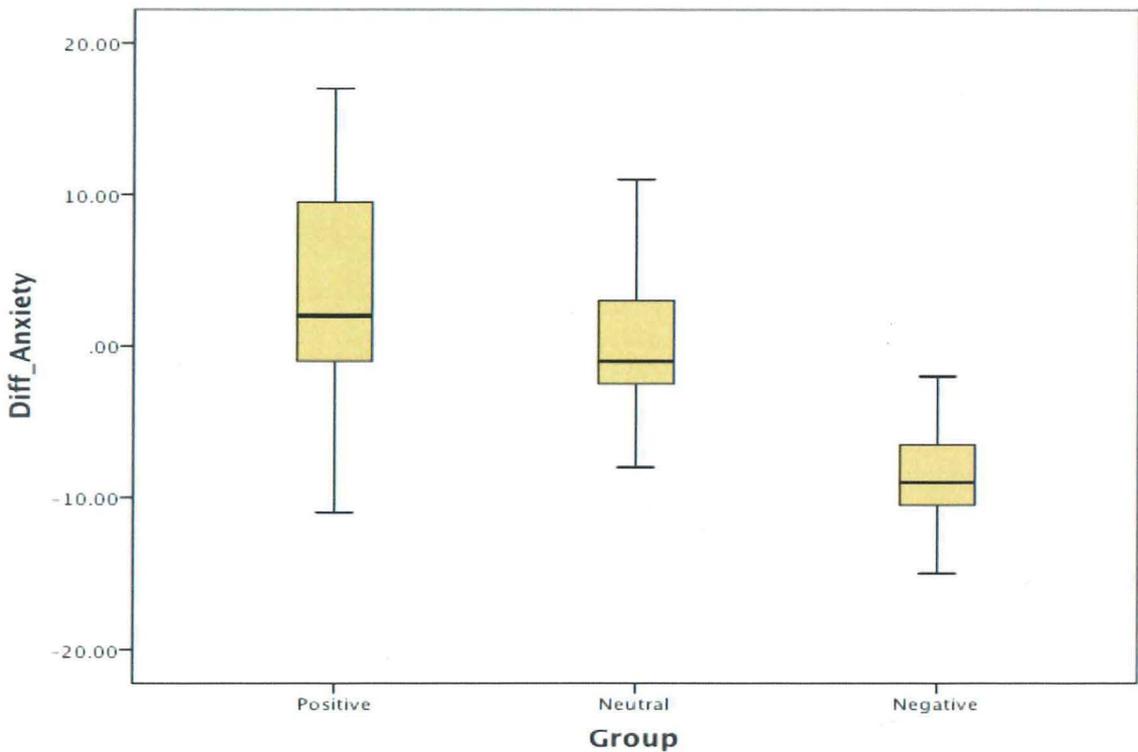
Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Diff_Anxiety Positive	.108	15	.200 <sup>*</sup>	.954	15	.594
Diff_Anxiety Neutral	.164	15	.200 <sup>*</sup>	.932	15	.289
Diff_Anxiety Negative	.123	15	.200 <sup>*</sup>	.952	15	.549

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking Outliers Again



### Checking Homogeneity of Variances

Test of Homogeneity of Variances

Diff\_Anxiety

Levene Statistic	df1	df2	Sig.
3.630	2	42	.035

Levene, H. (1960). Robust tests for equality of variances. In Ingram, O. & Harold, H., et al., 278-292.

**Main Analysis**

**Robust Tests of Equality of Means**

Diff\_Anxiety

	Statistic <sup>a</sup>	df1	df2	Sig.
Welch	21.812	2	26.114	.000

a. Asymptotically F distributed.

Moder, K. (2010). *Psychological Test and Assessment Modeling*, 52(4), 343-353

**Post Hoc Tests**

**Multiple Comparisons**

Dependent Variable: Diff\_Anxiety

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Positive	Neutral	2.60000	2.30233	.502	-2.9935	8.1935
		Negative	12.26667*	2.30233	.000	6.6732	17.8602
	Neutral	Positive	-2.60000	2.30233	.502	-8.1935	2.9935
		Negative	9.66667*	2.30233	.000	4.0732	15.2602
	Negative	Positive	-12.26667	2.30233	.000	-17.8602	-6.6732
		Neutral	-9.66667*	2.30233	.000	-15.2602	-4.0732
Games-Howell	Positive	Neutral	2.60000	2.62043	.589	-3.9535	9.1535
		Negative	12.26667*	2.45467	.000	6.0530	18.4803
	Neutral	Positive	-2.60000	2.62043	.589	-9.1535	3.9535
		Negative	9.66667*	1.73498	.000	5.3551	13.9782
	Negative	Positive	-12.26667	2.45467	.000	-18.4803	-6.0530
		Neutral	-9.66667*	1.73498	.000	-13.9782	-5.3551

\*. The mean difference is significant at the 0.05 level.

Abdi, H. & Williams, L. J. (2010). Tukey's Honestly Significant Difference (HSD) Test. In Neil Salkind (Ed.), *Encyclopedia of Research Design*. Thousand Oaks, CA.

Games, P. A. & Howell J. F. (1976). Pairwise Multiple Comparison Procedures with Unequal N's and/or Variances: A Monte Carlo Study, *Journal of Educational Statistics*, 1(2), 1976, 113-125.

2.2.2.2 Testing Differences in Computer Games Familiarity Between the Three Affective Groups

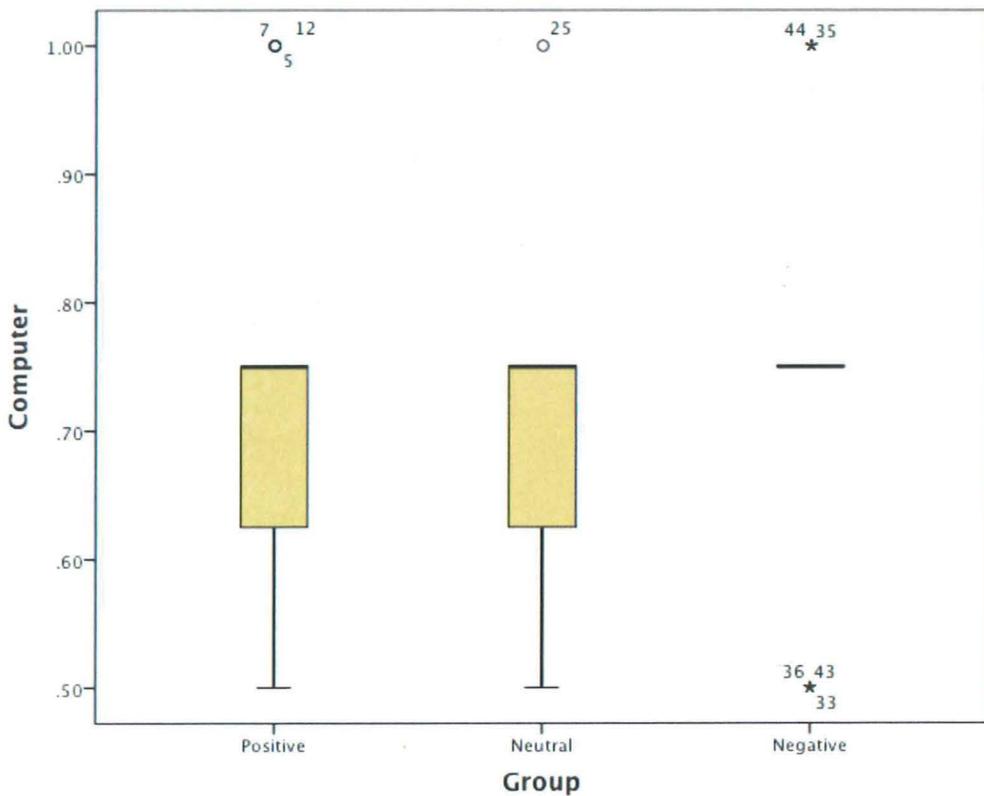
Tests of Normality

Tests of Normality

Group		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Computer	Positive	.271	15	.004	.815	15	.006
	Neutral	.373	15	.000	.734	15	.001
	Negative	.300	15	.001	.799	15	.004

a. Lilliefors Significance Correction

Checking for Outliers



Main Analysis

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Computer is the same across categories of Group.	Independent-Samples Kruskal-Wallis Test	.695	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Kruskal, W. & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the*

2.2.2.3 Testing Experimental Hypothesis 1

Testing Normality

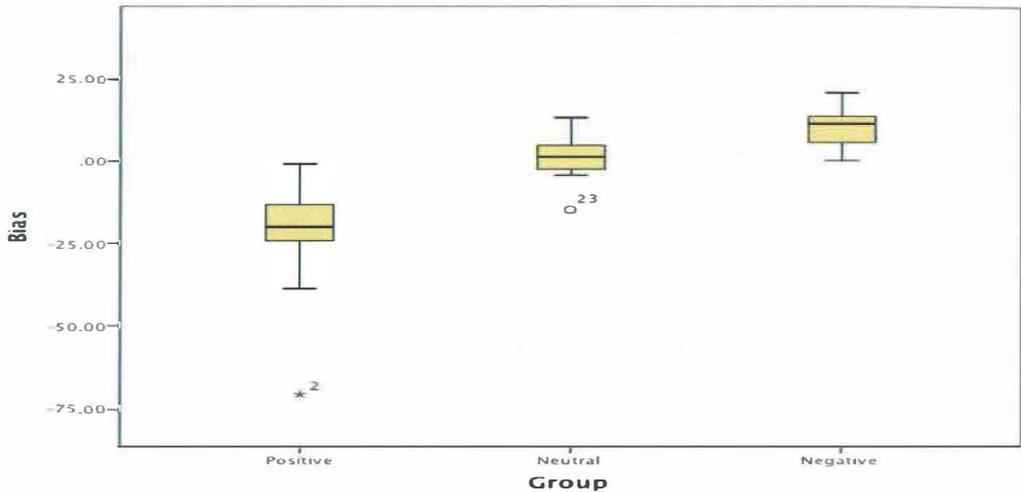
Tests of Normality

Group		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Bias	Positive	.226	15	.037	.842	15	.013
	Neutral	.141	15	.200*	.952	15	.555
	Negative	.144	15	.200*	.939	15	.373

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Testing for Outliers



Tests of Normality Again

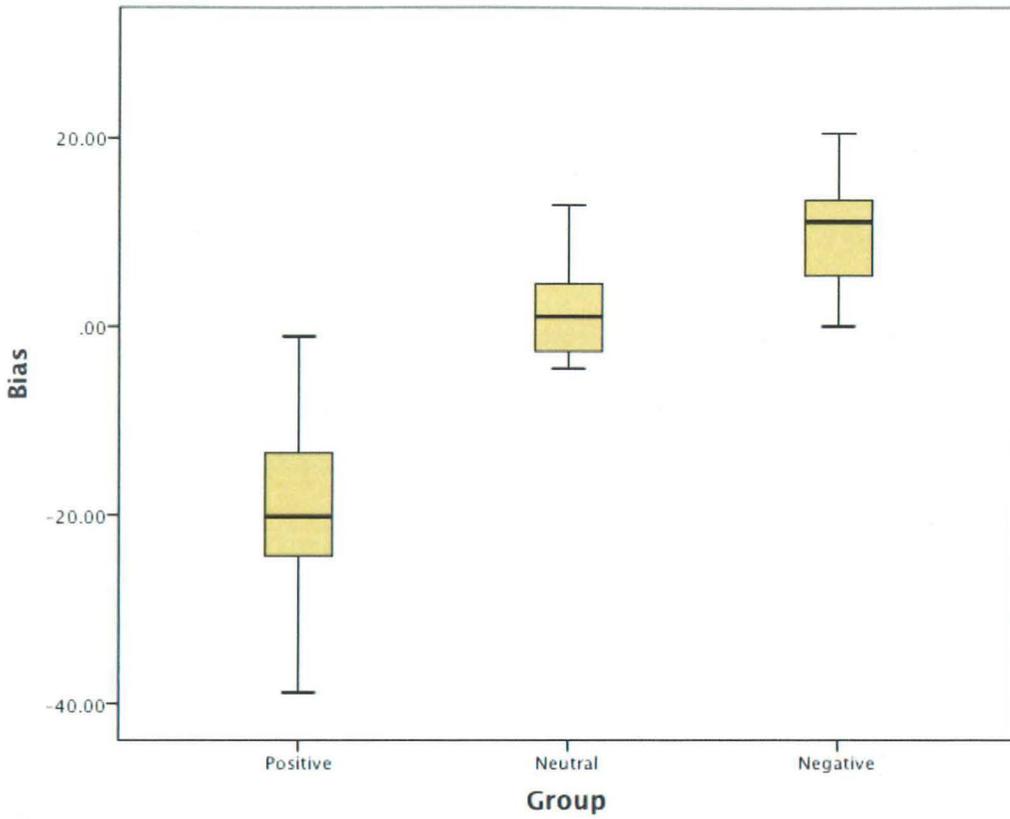
Tests of Normality

Group		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Bias	Positive	.158	15	.200*	.914	15	.154
	Neutral	.154	15	.200*	.895	15	.081
	Negative	.144	15	.200*	.939	15	.373

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking Outliers Again



### Test of Homogeneity of Variances

#### Test of Homogeneity of Variances

Bias			
Levene Statistic	df1	df2	Sig.
2.308	2	42	.112

### Main Analysis

## ANOVA

Bias

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7515.367	2	3757.684	51.637	.000
Within Groups	3056.364	42	72.771		
Total	10571.732	44			

Lehmann, E.L. (1959) Testing Statistical Hypotheses. John Wiley & Sons.

### Post-Hoc Analysis

#### Multiple Comparisons

Dependent Variable: Bias

Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Positive	Neutral	-22.31533*	3.11492	.000	-29.8830	-14.7476
	Negative	-30.60133*	3.11492	.000	-38.1690	-23.0336
Neutral	Positive	22.31533*	3.11492	.000	14.7476	29.8830
	Negative	-8.28600*	3.11492	.029	-15.8537	-.7183
Negative	Positive	30.60133*	3.11492	.000	23.0336	38.1690
	Neutral	8.28600*	3.11492	.029	.7183	15.8537

\*. The mean difference is significant at the 0.05 level.

### 2.2.2.4 Testing Experimental Hypothesis 1

#### Testing Normality

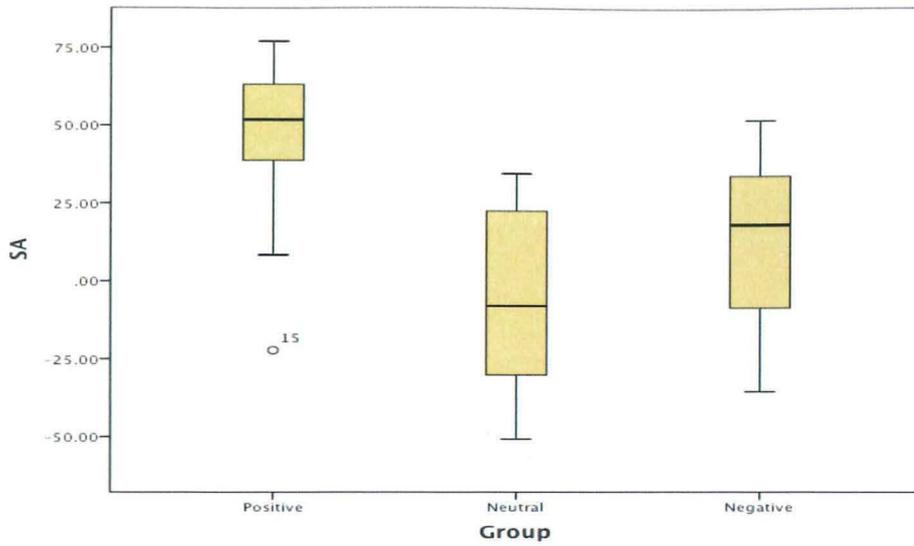
#### Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.	
SA	Positive	.228	15	.035	.872	15	.036
	Neutral	.163	15	.200*	.924	15	.220
	Negative	.148	15	.200*	.945	15	.444

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

#### Testing Outliers



### Testing Normality Again

Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SA Positive	.189	15	.157	.916	15	.167
SA Neutral	.163	15	.200*	.924	15	.220
SA Negative	.148	15	.200*	.945	15	.444

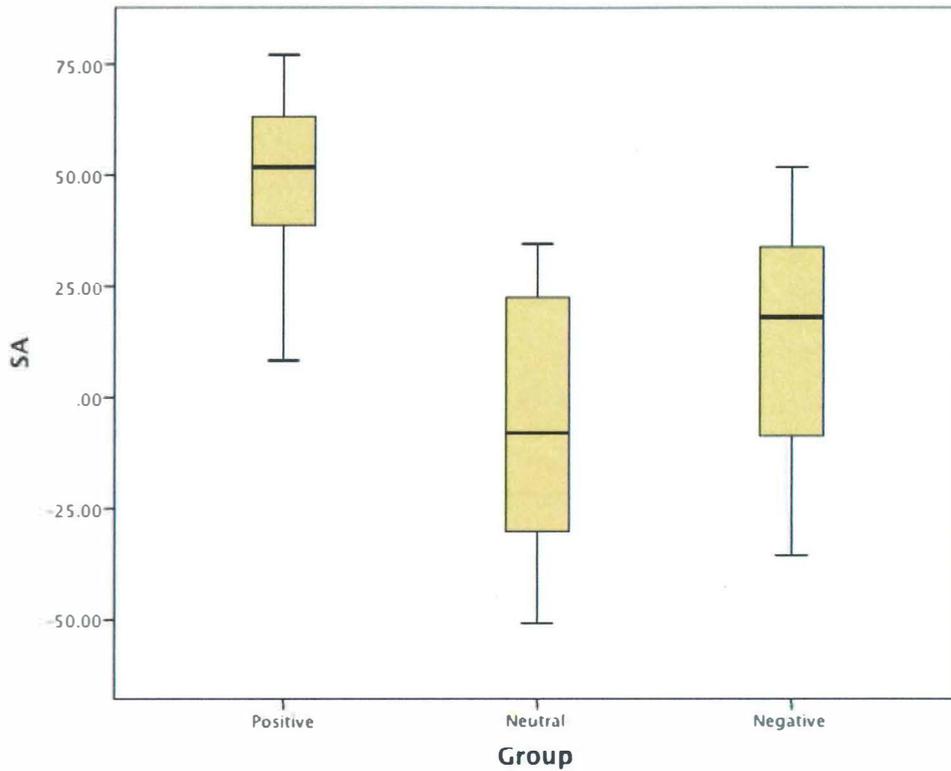
\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Testing

Outliers

Again



Test of Homogeneity of Variances

### Test of Homogeneity of Variances

SA

<u>Levene</u> Statistic	<u>df1</u>	<u>df2</u>	Sig.
2.051	2	42	.141

Main Analysis

### ANOVA

SA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	22581.443	2	11290.722	16.312	.000
Within Groups	29072.065	42	692.192		
Total	51653.508	44			

## Post-Hoc Analysis

### Multiple Comparisons

Dependent Variable: SA

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Positive	Neutral	53.54400	9.60689	.000	30.2041	76.8839
		Negative	37.16067*	9.60689	.001	13.8208	60.5005
	Neutral	Positive	-53.54400	9.60689	.000	-76.8839	-30.2041
		Negative	-16.38333	9.60689	.215	-39.7232	6.9565
	Negative	Positive	-37.16067	9.60689	.001	-60.5005	-13.8208
		Neutral	16.38333	9.60689	.215	-6.9565	39.7232
Games-Howell	Positive	Neutral	53.54400	9.20080	.000	30.6716	76.4164
		Negative	37.16067*	9.15536	.001	14.4064	59.9150
	Neutral	Positive	-53.54400	9.20080	.000	-76.4164	-30.6716
		Negative	-16.38333	10.41160	.273	-42.1454	9.3787
	Negative	Positive	-37.16067	9.15536	.001	-59.9150	-14.4064
		Neutral	16.38333	10.41160	.273	-9.3787	42.1454

\*. The mean difference is significant at the 0.05 level.

### 2.2.2.6 Testing Differences in Confidence in Answers Between the Three Groups

#### Testing Normality

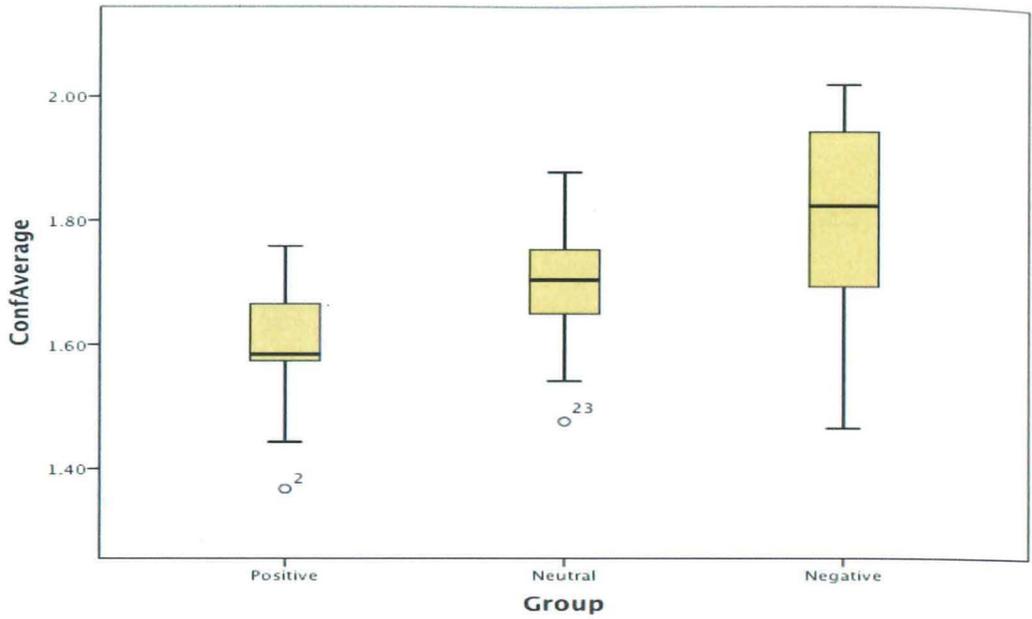
##### Tests of Normality

Group		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
ConfAverage	Positive	.210	15	.074	.929	15	.262
	Neutral	.127	15	.200*	.974	15	.917
	Negative	.132	15	.200*	.931	15	.286

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

#### Checking For Outliers



**Testing For Normality Again**

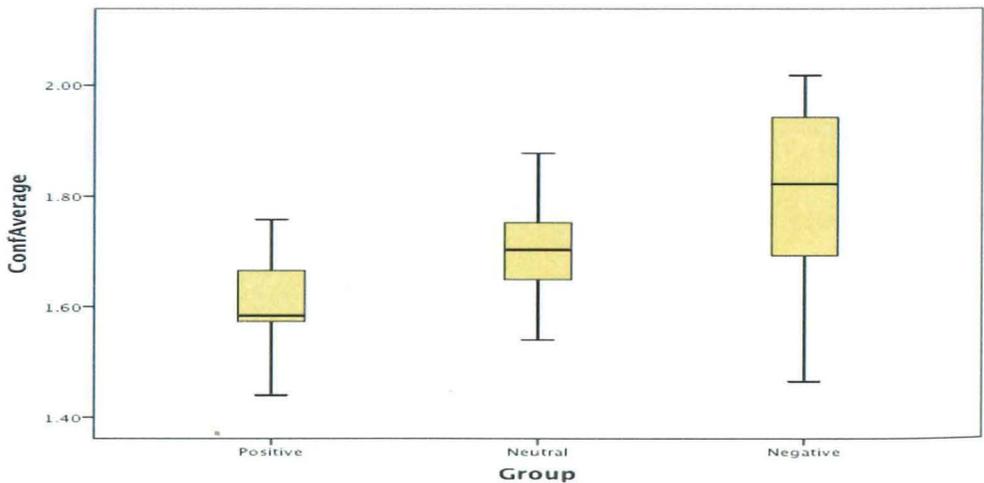
**Tests of Normality**

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
ConfAverage Positive	.182	15	.192	.919	15	.189
ConfAverage Neutral	.122	15	.200*	.972	15	.887
ConfAverage Negative	.132	15	.200*	.931	15	.286

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

**Checking For Outliers Again**



**Test of Homogeneity of Variances**

## Test of Homogeneity of Variances

ConfAverage

Levene Statistic	df1	df2	Sig.
2.988	2	42	.061

### Main Analysis

## ANOVA

ConfAverage

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.334	2	.167	11.817	.000
Within Groups	.594	42	.014		
Total	.929	44			

### Post-Hoc Analysis

#### Multiple Comparisons

Dependent Variable: ConfAverage

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Positive	Neutral	-.09422	.04343	.088	-.1997	.0113
		Negative	-.21075*	.04343	.000	-.3163	-.1052
	Neutral	Positive	.09422	.04343	.088	-.0113	.1997
		Negative	-.11653*	.04343	.027	-.2220	-.0110
	Negative	Positive	.21075*	.04343	.000	.1052	.3163
		Neutral	.11653*	.04343	.027	.0110	.2220
Games-Howell	Positive	Neutral	-.09422	.03489	.030	-.1806	-.0079
		Negative	-.21075*	.04752	.001	-.3295	-.0920
	Neutral	Positive	.09422	.03489	.030	.0079	.1806
		Negative	-.11653	.04673	.051	-.2336	.0006
	Negative	Positive	.21075*	.04752	.001	.0920	.3295
		Neutral	.11653	.04673	.051	-.0006	.2336

\*. The mean difference is significant at the 0.05 level.

4.2.2.1 Behavioural Analysis

Data Screening – checking normality

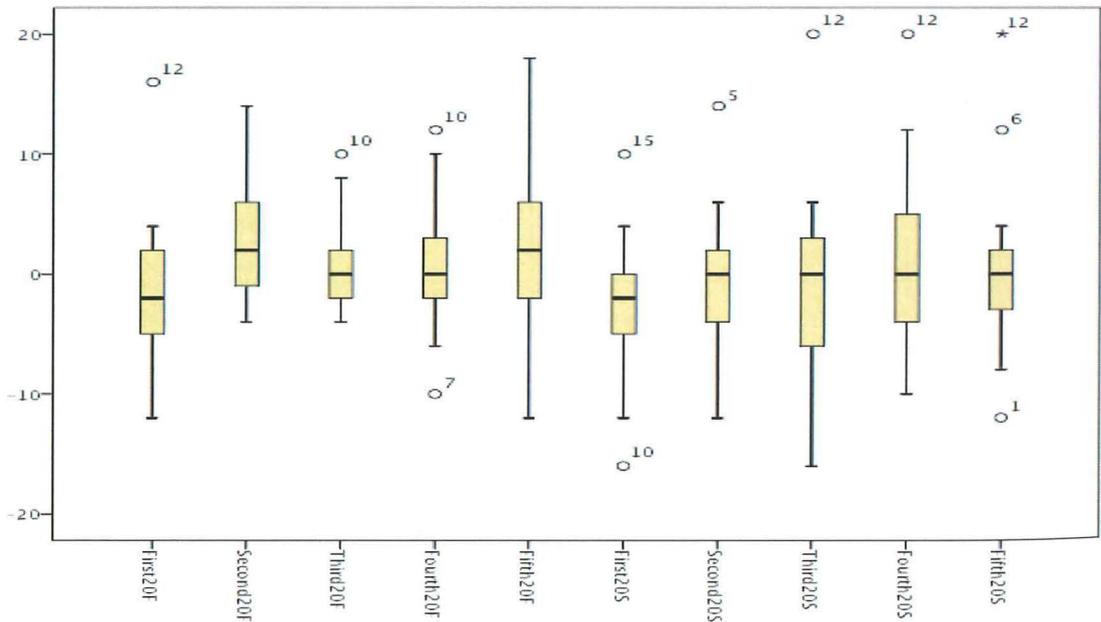
Tests of Normality

	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
First20F	.157	15	.200 <sup>*</sup>	.924	15	.221
Second20F	.153	15	.200 <sup>*</sup>	.935	15	.329
Third20F	.237	15	.023	.854	15	.020
Fourth20F	.146	15	.200 <sup>*</sup>	.968	15	.832
Fifth20F	.186	15	.172	.950	15	.532
First20S	.160	15	.200 <sup>*</sup>	.964	15	.760
Second20S	.191	15	.146	.947	15	.486
Third20S	.149	15	.200 <sup>*</sup>	.943	15	.422
Fourth20S	.115	15	.200 <sup>*</sup>	.954	15	.590
Fifth20S	.224	15	.041	.898	15	.087

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Checking for Outliers



Checking Normalization Again

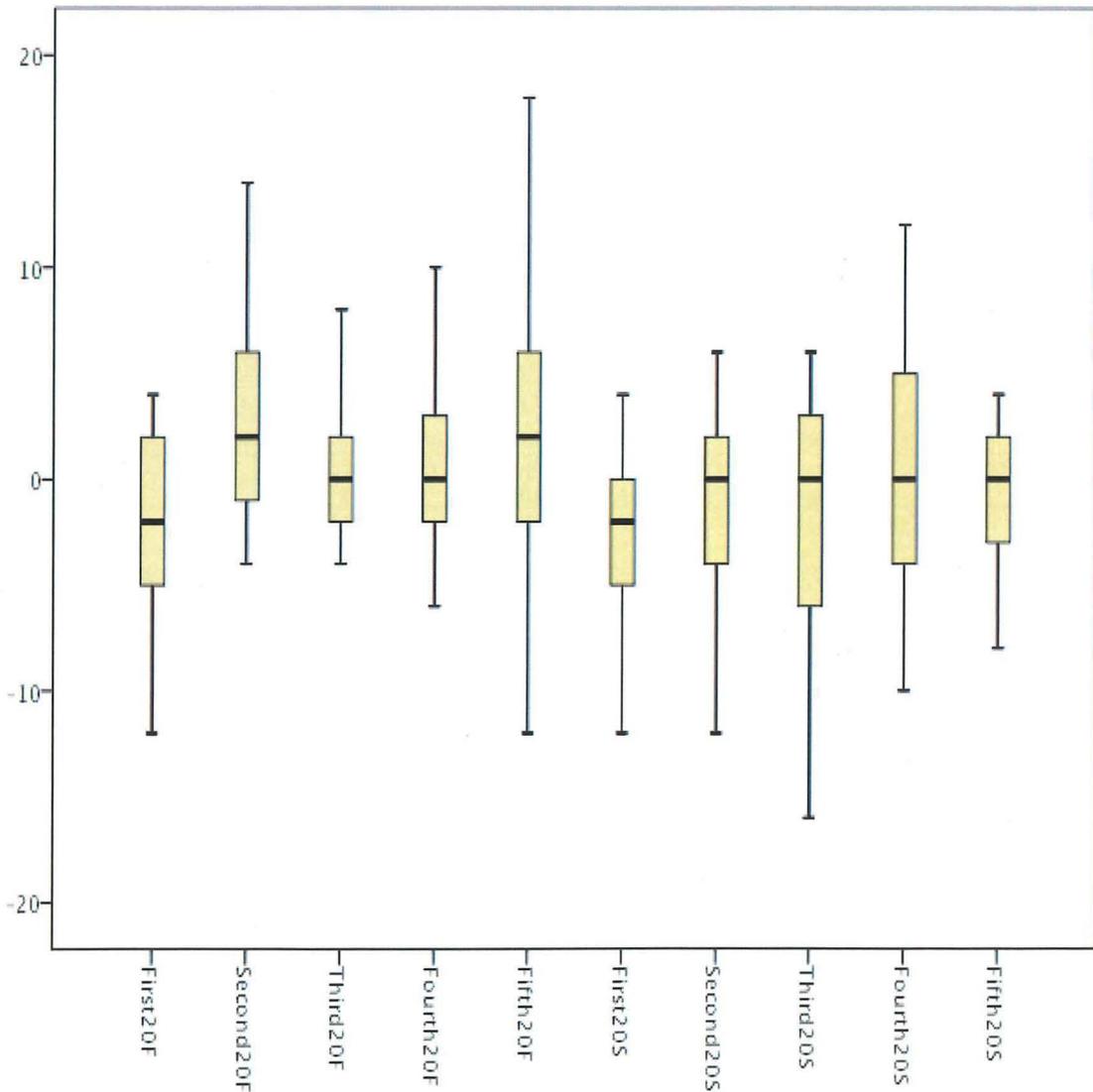
### Tests of Normality

	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
First20F	.152	15	.200	.944	15	.435
Second20F	.153	15	.200*	.935	15	.329
Third20F	.220	15	.048	.844	15	.014
Fourth20F	.164	15	.200*	.929	15	.267
Fifth20F	.186	15	.172	.950	15	.532
First20S	.172	15	.200*	.917	15	.174
Second20S	.233	15	.027	.906	15	.116
Third20S	.207	15	.085	.928	15	.258
Fourth20S	.111	15	.200*	.964	15	.765
Fifth20S	.245	15	.016	.889	15	.064

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking for Outliers Again



### Checking Sphericity

Mauchly's Test of Sphericity<sup>a</sup>

Measure: MEASURE\_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon <sup>b</sup>		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Phase	1.000	.000	0	.	1.000	1.000	1.000
SelectionBlocks	.397	11.458	9	.250	.723	.932	.250
Phase * SelectionBlocks	.712	4.223	9	.897	.871	1.000	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

- a. Design: Intercept  
Within Subjects Design: Phase + SelectionBlocks + Phase \* SelectionBlocks
- b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Mauchly, J.W. (1940). Significance Test for Sphericity of a Normal n-Variate Distribution. *The Annals of Mathematical Statistics*, 11(2), 204–209.

Main Analysis

Tests of Within-Subjects Effects

Measure: MEASURE\_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Phase	Sphericity Assumed	146.027	1	146.027	2.176	.162	.135
	Greenhouse-Geisser	146.027	1.000	146.027	2.176	.162	.135
	Huynh-Feldt	146.027	1.000	146.027	2.176	.162	.135
	Lower-bound	146.027	1.000	146.027	2.176	.162	.135
Error(Phase)	Sphericity Assumed	939.573	14	67.112			
	Greenhouse-Geisser	939.573	14.000	67.112			
	Huynh-Feldt	939.573	14.000	67.112			
	Lower-bound	939.573	14.000	67.112			
Blocks	Sphericity Assumed	293.173	4	73.293	3.010	.026	.177
	Greenhouse-Geisser	293.173	2.893	101.356	3.010	.043	.177
	Huynh-Feldt	293.173	3.726	78.681	3.010	.029	.177
	Lower-bound	293.173	1.000	293.173	3.010	.105	.177
Error(Blocks)	Sphericity Assumed	1363.627	56	24.350			
	Greenhouse-Geisser	1363.627	40.495	33.674			
	Huynh-Feldt	1363.627	52.165	26.140			
	Lower-bound	1363.627	14.000	97.402			
Phase * Blocks	Sphericity Assumed	94.240	4	23.560	.852	.498	.057
	Greenhouse-Geisser	94.240	3.484	27.049	.852	.486	.057
	Huynh-Feldt	94.240	4.000	23.560	.852	.498	.057
	Lower-bound	94.240	1.000	94.240	.852	.372	.057
Error(Phase*Blocks)	Sphericity Assumed	1548.160	56	27.646			
	Greenhouse-Geisser	1548.160	48.777	31.740			
	Huynh-Feldt	1548.160	56.000	27.646			
	Lower-bound	1548.160	14.000	110.583			

Greenhouse, S.W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika*, 24, 95-112.

## Post-Hoc Analysis

### Tests of Within-Subjects Contrasts

Measure: MEASURE\_1

Source	Phase	Blocks	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Phase	Linear		29.205	1	29.205	2.176	.162	.135
Error(Phase)	Linear		187.915	14	13.422			
Blocks		Level 1 vs. Level 2	388.800	1	388.800	8.964	.010	.390
		Level 2 vs. Level 3	38.533	1	38.533	1.628	.223	.104
		Level 3 vs. Level 4	43.200	1	43.200	.888	.362	.060
		Level 4 vs. Level 5	.533	1	.533	.013	.910	.001
Error(Blocks)		Level 1 vs. Level 2	607.200	14	43.371			
		Level 2 vs. Level 3	331.467	14	23.676			
		Level 3 vs. Level 4	680.800	14	48.629			
		Level 4 vs. Level 5	563.467	14	40.248			
Phase * Blocks	Linear	Level 1 vs. Level 2	76.800	1	76.800	1.794	.202	.114
		Level 2 vs. Level 3	3.333	1	3.333	.064	.804	.005
		Level 3 vs. Level 4	76.800	1	76.800	1.896	.190	.119
		Level 4 vs. Level 5	90.133	1	90.133	1.942	.185	.122
Error(Phase*Blocks)	Linear	Level 1 vs. Level 2	599.200	14	42.800			
		Level 2 vs. Level 3	726.667	14	51.905			
		Level 3 vs. Level 4	567.200	14	40.514			
		Level 4 vs. Level 5	649.867	14	46.419			

#### 4.2.2.2.1 EEG Analysis for the First 100 Trials – Exploring Somatic Markers' EEG Correlates

### Testing Normality

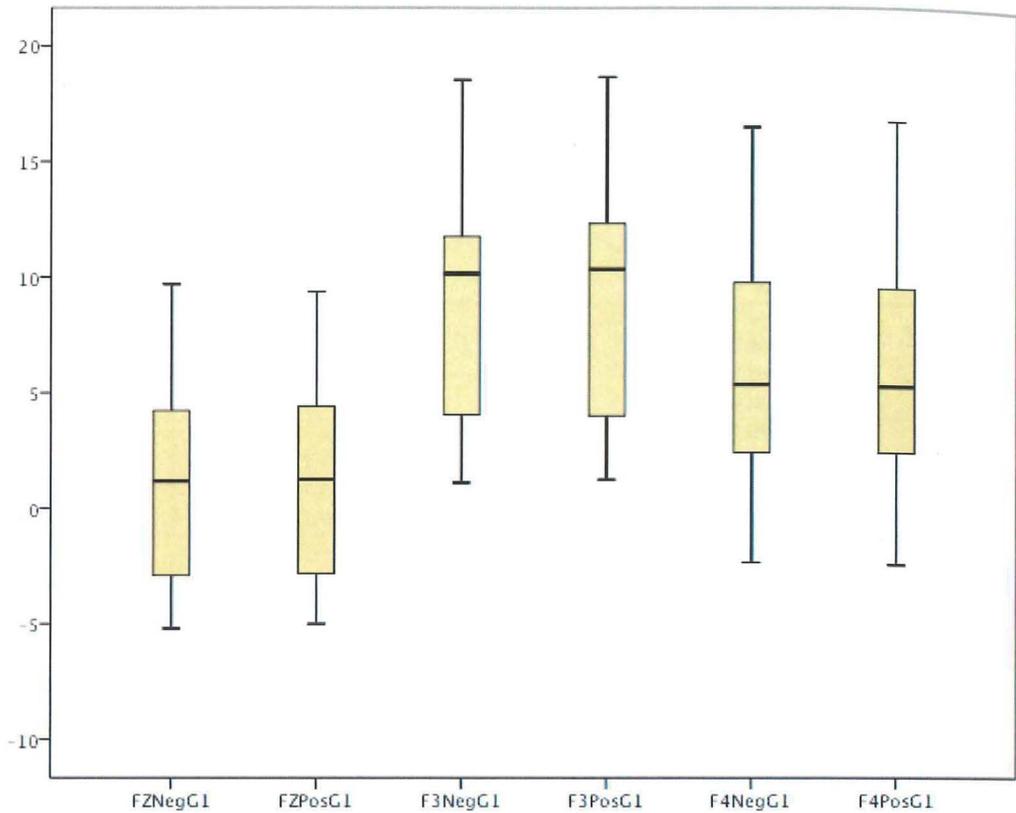
#### Tests of Normality

	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
FZNegG1	.137	11	.200*	.952	11	.674
FZPosG1	.142	11	.200*	.947	11	.602
F3NegG1	.154	11	.200*	.950	11	.638
F3PosG1	.153	11	.200*	.945	11	.581
F4NegG1	.174	11	.200*	.943	11	.557
F4PosG1	.171	11	.200*	.946	11	.589

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

## Checking For Outliers



## Testing Sphericity

### Mauchly's Test of Sphericity<sup>a</sup>

Measure: EEG\_microvolt

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon <sup>b</sup>		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ElectrodePositive	.633	4.120	2	.127	.731	.825	.500
Responses	1.000	.000	0	.	1.000	1.000	1.000
ElectrodePositive * Responses	.864	1.312	2	.519	.881	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: ElectrodePositive + Responses + ElectrodePositive \* Responses

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

## Main Analysis

Tests of Within-Subjects Effects

Measure: EEG

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ElectrodePosition	Sphericity Assumed	667.677	2	333.839	6.523	.007	.395
	Greenhouse-Geisser	667.677	1.463	456.453	6.523	.014	.395
	Huynh-Feldt	667.677	1.650	404.544	6.523	.011	.395
	Lower-bound	667.677	1.000	667.677	6.523	.029	.395
Error(ElectrodePosition)	Sphericity Assumed	1023.621	20	51.181			
	Greenhouse-Geisser	1023.621	14.628	69.979			
	Huynh-Feldt	1023.621	16.504	62.021			
	Lower-bound	1023.621	10.000	102.362			
Response	Sphericity Assumed	.096	1	.096	1.449	.256	.127
	Greenhouse-Geisser	.096	1.000	.096	1.449	.256	.127
	Huynh-Feldt	.096	1.000	.096	1.449	.256	.127
	Lower-bound	.096	1.000	.096	1.449	.256	.127
Error(Response)	Sphericity Assumed	.661	10	.066			
	Greenhouse-Geisser	.661	10.000	.066			
	Huynh-Feldt	.661	10.000	.066			
	Lower-bound	.661	10.000	.066			
ElectrodePosition * Response	Sphericity Assumed	.197	2	.098	5.255	.015	.344
	Greenhouse-Geisser	.197	1.761	.112	5.255	.019	.344
	Huynh-Feldt	.197	2.000	.098	5.255	.015	.344
	Lower-bound	.197	1.000	.197	5.255	.045	.344
Error (ElectrodePosition*Response)	Sphericity Assumed	.375	20	.019			
	Greenhouse-Geisser	.375	17.611	.021			
	Huynh-Feldt	.375	20.000	.019			
	Lower-bound	.375	10.000	.037			

Post-Hoc Analysis

One-way ANOVA - Alpha Power for Disadvantagous Responses

Mauchly's Test of Sphericity<sup>a</sup>

Measure: EEG\_microvolt

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon <sup>b</sup>		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ElectrodePositions	.625	4.231	2	.121	.727	.819	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

- a. Design: Intercept  
Within Subjects Design: ElectrodePositions
- b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: EEG\_microvolt

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ElectrodePositions	Sphericity Assumed	333.614	2	166.807	6.563	.006	.396
	Greenhouse-Geisser	333.614	1.454	229.369	6.563	.014	.396
	Huynh-Feldt	333.614	1.638	203.646	6.563	.011	.396
	Lower-bound	333.614	1.000	333.614	6.563	.028	.396
Error(ElectrodePositions)	Sphericity Assumed	508.364	20	25.418			
	Greenhouse-Geisser	508.364	14.545	34.952			
	Huynh-Feldt	508.364	16.382	31.032			
	Lower-bound	508.364	10.000	50.836			

### Pairwise Comparisons

Measure: EEG\_microvolt

(i) ElectrodePositions	(j) ElectrodePositions	Mean Difference (I-J)	Std. Error	Sig. <sup>b</sup>	95% Confidence Interval for Difference <sup>b</sup>	
					Lower Bound	Upper Bound
1	2	-7.603	2.043	.012	-13.468	-1.739
	3	-5.263	2.695	.238	-12.999	2.473
2	1	7.603	2.043	.012	1.739	13.468
	3	2.341	1.557	.491	-2.128	6.809
3	1	5.263	2.695	.238	-2.473	12.999
	2	-2.341	1.557	.491	-6.809	2.128

Based on estimated marginal means

<sup>a</sup>. The mean difference is significant at the

<sup>b</sup>. Adjustment for multiple comparisons: Bonferroni.

Dunn, O.J. (1961). Multiple Comparisons Among Means. *Journal of the American Statistical Association*, 56, 52-64.

### One-way ANOVA - Alpha Power for Advantagous Responses

#### Mauchly's Test of Sphericity<sup>a</sup>

Measure: EEG\_microvolt

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon <sup>b</sup>		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ElectrodePositions	.641	4.005	2	.135	.736	.832	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: ElectrodePositions

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

#### Tests of Within-Subjects Effects

Measure: EEG\_microvolt

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ElectrodePositions	Sphericity Assumed	334.260	2	167.130	6.483	.007	.393
	Greenhouse-Geisser	334.260	1.472	227.153	6.483	.015	.393
	Huynh-Feldt	334.260	1.663	200.944	6.483	.011	.393
	Lower-bound	334.260	1.000	334.260	6.483	.029	.393
Error(ElectrodePositions)	Sphericity Assumed	515.632	20	25.782			
	Greenhouse-Geisser	515.632	14.715	35.041			
	Huynh-Feldt	515.632	16.634	30.998			
	Lower-bound	515.632	10.000	51.563			

### Pairwise Comparisons

Measure: EEG\_microvolt

(I) ElectrodePositions	(J) ElectrodePositions	Mean Difference (I-J)	Std. Error	Sig. <sup>b</sup>	95% Confidence Interval for Difference <sup>b</sup>	
					Lower Bound	Upper Bound
1	2	-7.664	2.035	.011	-13.506	-1.823
	3	-5.067	2.710	.273	-12.847	2.712
2	1	7.664	2.035	.011	1.823	13.506
	3	2.597	1.604	.410	-2.007	7.201
3	1	5.067	2.710	.273	-2.712	12.847
	2	-2.597	1.604	.410	-7.201	2.007

Based on estimated marginal means

<sup>a</sup>. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

### Wilcoxon Signed-Rank – Alpha Power for Responses for each Electrode Position

#### Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between FZNegG1 and FZPosG1 equals 0.	Related-Samples Wilcoxon Signed Rank Test	.050	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Wilcoxon, F. (1945). Individual comparisons by ranking methods. *Biometrics Bulletin*, 1(6), 80–83.

### 4.2.2.2.2 EEG Analysis for the Second 100 Trials – Exploring Somatic Markers' EEG Correlates

#### Test of Normality

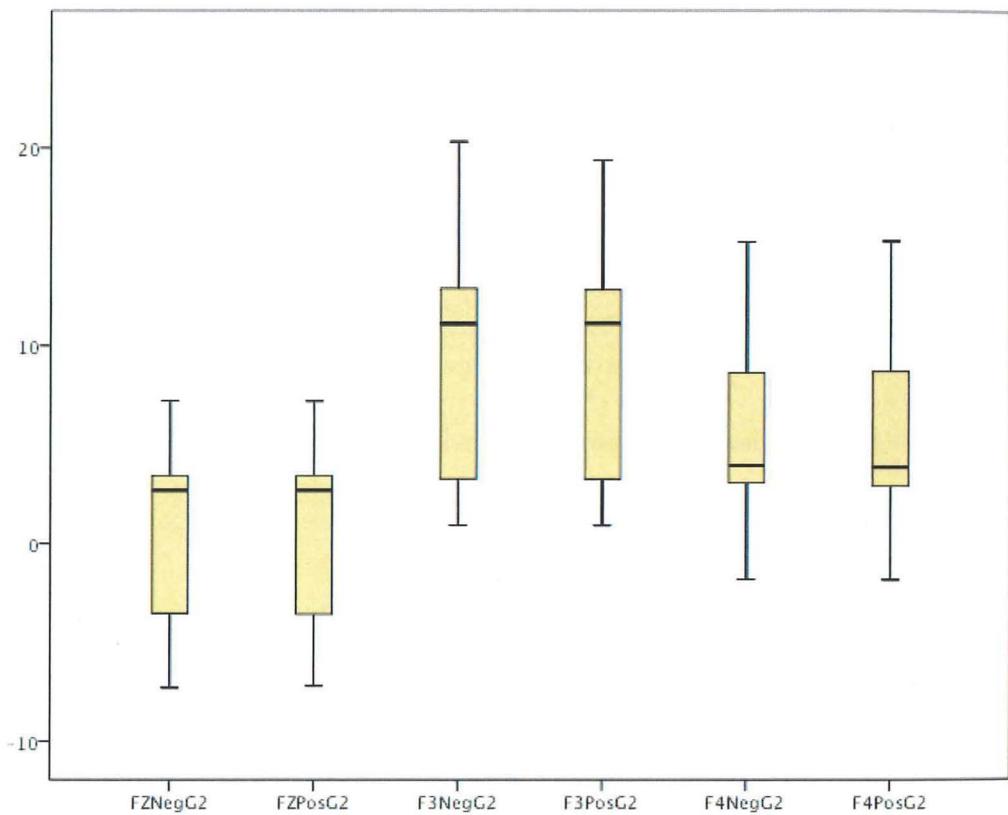
### Tests of Normality

	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
FZNegG2	.241	11	.074	.934	11	.449
FZPosG2	.240	11	.075	.932	11	.427
F3NegG2	.169	11	.200 <sup>*</sup>	.933	11	.445
F3PosG2	.171	11	.200 <sup>*</sup>	.928	11	.388
F4NegG2	.203	11	.200 <sup>*</sup>	.928	11	.391
F4PosG2	.205	11	.200 <sup>*</sup>	.926	11	.368

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking For Outliers



### Tests of Sphericity

Mauchly's Test of Sphericity<sup>a</sup>

Measure: EEG\_microvolt

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon <sup>b</sup>		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ElectrodePositions	.908	.864	2	.649	.916	1.000	.500
Responses	1.000	.000	0	.	1.000	1.000	1.000
ElectrodePositions * Responses	.217	13.738	2	.001	.561	.582	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

- a. Design: Intercept  
Within Subjects Design: ElectrodePositions + Responses + ElectrodePositions \* Responses
- b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Main Analysis

Tests of Within-Subjects Effects

Measure: EEG\_microvolt

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ElectrodePositions	Sphericity Assumed	932.638	2	466.319	9.617	.001	.490
	Greenhouse-Geisser	932.638	1.832	509.024	9.617	.002	.490
	Huynh-Feldt	932.638	2.000	466.319	9.617	.001	.490
	Lower-bound	932.638	1.000	932.638	9.617	.011	.490
Error(ElectrodePositions)	Sphericity Assumed	969.764	20	48.488			
	Greenhouse-Geisser	969.764	18.322	52.929			
	Huynh-Feldt	969.764	20.000	48.488			
	Lower-bound	969.764	10.000	96.976			
Responses	Sphericity Assumed	.077	1	.077	3.692	.084	.270
	Greenhouse-Geisser	.077	1.000	.077	3.692	.084	.270
	Huynh-Feldt	.077	1.000	.077	3.692	.084	.270
	Lower-bound	.077	1.000	.077	3.692	.084	.270
Error(Responses)	Sphericity Assumed	.208	10	.021			
	Greenhouse-Geisser	.208	10.000	.021			
	Huynh-Feldt	.208	10.000	.021			
	Lower-bound	.208	10.000	.021			
ElectrodePositions * Responses	Sphericity Assumed	.057	2	.029	1.889	.177	.159
	Greenhouse-Geisser	.057	1.122	.051	1.889	.197	.159
	Huynh-Feldt	.057	1.165	.049	1.889	.197	.159
	Lower-bound	.057	1.000	.057	1.889	.199	.159
Error (ElectrodePositions * Responses)	Sphericity Assumed	.302	20	.015			
	Greenhouse-Geisser	.302	11.219	.027			
	Huynh-Feldt	.302	11.648	.026			
	Lower-bound	.302	10.000	.030			

Post-Hoc Analysis

Pairwise Comparisons

Measure: EEG\_microvolt

(I) ElectrodePositions	(J) ElectrodePositions	Mean Difference (I-J)	Std. Error	Sig. <sup>b</sup>	95% Confidence Interval for Difference <sup>b</sup>	
					Lower Bound	Upper Bound
1	2	-9.067	2.093	.004	-15.075	-3.059
	3	-5.922	2.361	.093	-12.699	.856
2	1	9.067	2.093	.004	3.059	15.075
	3	3.146	1.807	.337	-2.041	8.333
3	1	5.922	2.361	.093	-.856	12.699
	2	-3.146	1.807	.337	-8.333	2.041

Based on estimated marginal means

- <sup>a</sup>. The mean difference is significant at the
- b. Adjustment for multiple comparisons: Bonferroni.

CHAPTER 5 AND 6

The analysis for the Chapters 5 and 6 were conducted exactly the same as for Chapter 4.

CHAPTER 7

7.2.2.1 Anxiety Levels Control Results

Test of Normality

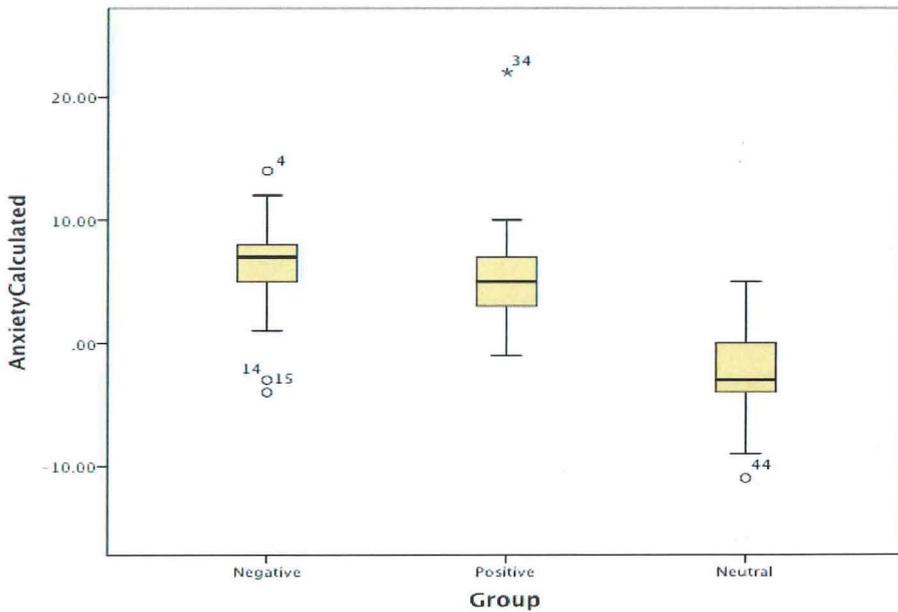
Tests of Normality

AnxietyCalculated	Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
	Negative	.237	17	.012	.904	17	.080
	Positive	.208	17	.048	.833	17	.006
	Neutral	.160	17	.200 <sup>*</sup>	.971	17	.842

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Checking for Outliers



Testing Normality Again

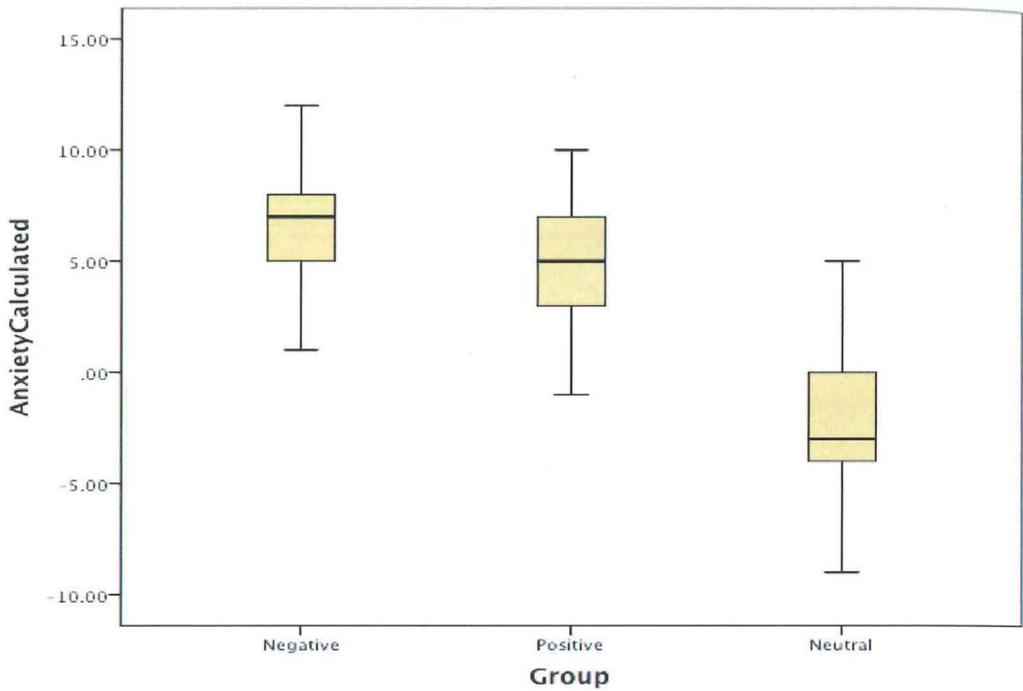
Tests of Normality

AnxietyCalculated	Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
	Negative	.159	17	.200	.918	17	.137
	Positive	.143	17	.200 <sup>*</sup>	.957	17	.581
	Neutral	.140	17	.200 <sup>*</sup>	.966	17	.746

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

**Checking Outliers Again**



**Checking Homogeneity of Variances**

**Test of Homogeneity of Variances**

AnxietyCalculated

Levene Statistic	df1	df2	Sig.
.346	2	48	.709

Main

Analysis

**ANOVA**

AnxietyCalculated

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	706.863	2	353.431	28.236	.000
Within Groups	600.824	48	12.517		
Total	1307.686	50			

## Post Hoc Tests

### Multiple Comparisons

Dependent Variable: AnxietyCalculated

	(i) Group	(j) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Negative	Positive	1.47059	1.21351	.452	-1.4643	4.4054
		Neutral	8.52941 <sup>*</sup>	1.21351	.000	5.5946	11.4643
	Positive	Negative	-1.47059	1.21351	.452	-4.4054	1.4643
		Neutral	7.05882 <sup>*</sup>	1.21351	.000	4.1240	9.9937
	Neutral	Negative	-8.52941	1.21351	.000	-11.4643	-5.5946
		Positive	-7.05882 <sup>*</sup>	1.21351	.000	-9.9937	-4.1240
Games-Howell	Negative	Positive	1.47059	1.13930	.411	-1.3291	4.2703
		Neutral	8.52941 <sup>*</sup>	1.24541	.000	5.4645	11.5943
	Positive	Negative	-1.47059	1.13930	.411	-4.2703	1.3291
		Neutral	7.05882 <sup>*</sup>	1.25251	.000	3.9771	10.1406
	Neutral	Negative	-8.52941	1.24541	.000	-11.5943	-5.4645
		Positive	-7.05882 <sup>*</sup>	1.25251	.000	-10.1406	-3.9771

<sup>\*</sup>. The mean difference is significant at the 0.05 level.

## 7.2.2.2 Result of Arousal Ratings

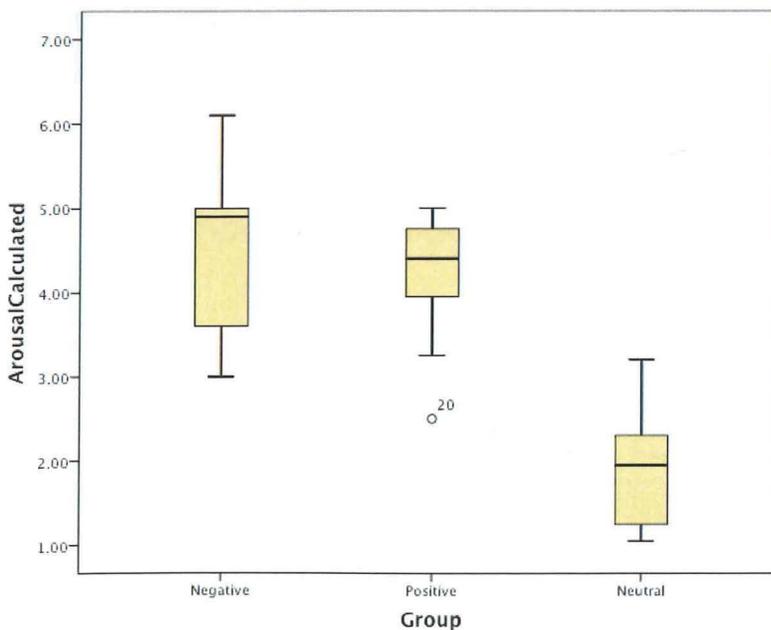
### Tests of Normality

#### Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
ArousalCalculated						
Negative	.174	17	.180	.922	17	.163
Positive	.232	17	.016	.888	17	.042
Neutral	.172	17	.194	.922	17	.160

a. Lilliefors Significance Correction

### Checking for Outliers



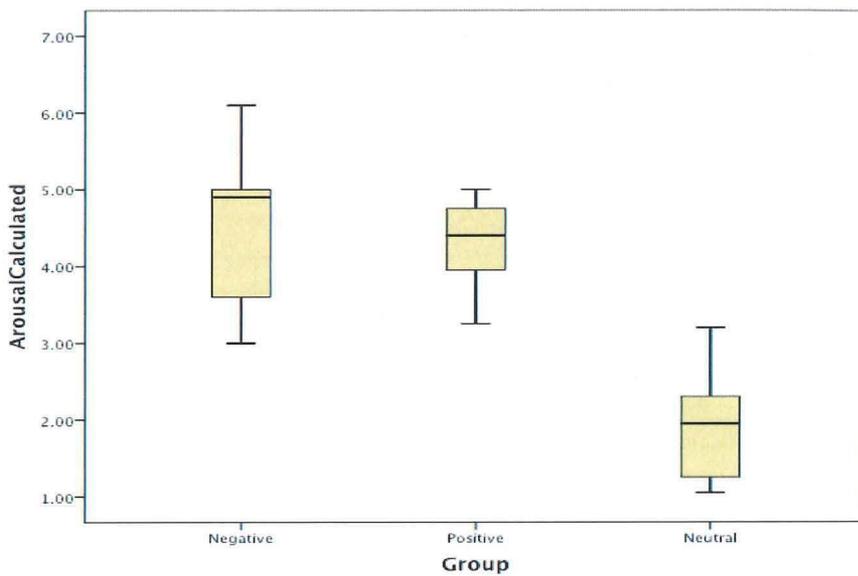
### Testing Normality Again

Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
ArousalCalculated						
Negative	.174	17	.180	.922	17	.163
Positive	.217	17	.033	.882	17	.034
Neutral	.172	17	.194	.922	17	.160

a. Lilliefors Significance Correction

### Checking Outliers Again



### Checking Homogeneity of Variances

Test of Homogeneity of Variances

ArousalCalculated

Levene Statistic	df1	df2	Sig.
4.484	2	48	.016

**Main Analysis**

**Robust Tests of Equality of Means**

ArousalCalculated

	Statistic <sup>a</sup>	df1	df2	Sig.
Welch	68.961	2	30.808	.000

a. Asymptotically F distributed.

**Post Hoc Tests**

**Multiple Comparisons**

Dependent Variable: ArousalCalculated

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Negative	Positive	.26765	.27327	.593	-.3932	.9285
		Neutral	2.63824*	.27327	.000	1.9773	3.2991
	Positive	Negative	-.26765	.27327	.593	-.9285	.3932
		Neutral	2.37059*	.27327	.000	1.7097	3.0315
	Neutral	Negative	-2.63824*	.27327	.000	-3.2991	-1.9773
		Positive	-2.37059*	.27327	.000	-3.0315	-1.7097
Games-Howell	Negative	Positive	.26765	.29263	.636	-.4602	.9955
		Neutral	2.63824*	.30109	.000	1.8921	3.3844
	Positive	Negative	-.26765	.29263	.636	-.9955	.4602
		Neutral	2.37059*	.21849	.000	1.8334	2.9078
	Neutral	Negative	-2.63824*	.30109	.000	-3.3844	-1.8921
		Positive	-2.37059*	.21849	.000	-2.9078	-1.8334

\*. The mean difference is significant at the 0.05 level.

*7.2.2.3 Result of Valence Measures*

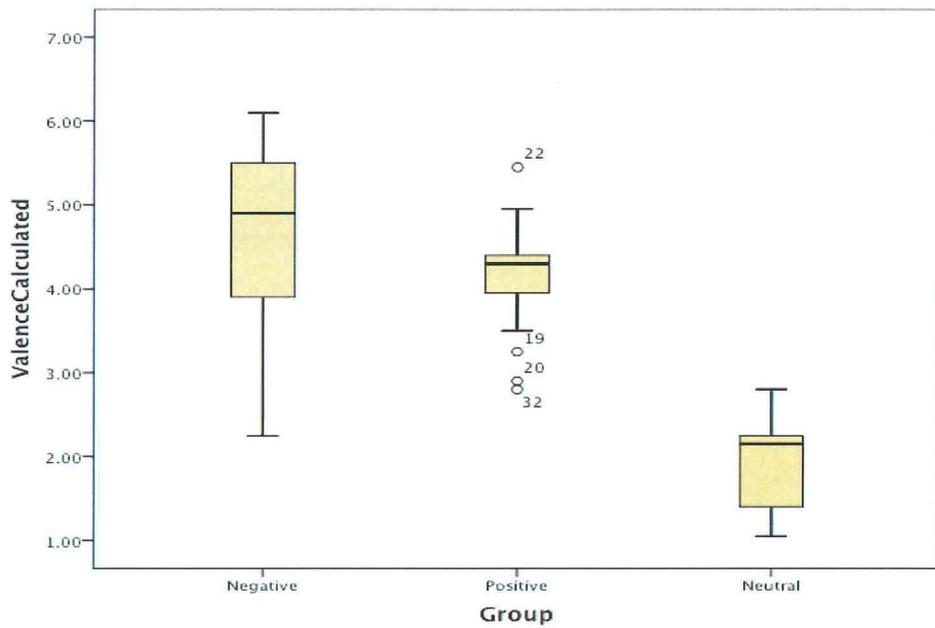
**Tests of Normality**

**Tests of Normality**

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.	
ValenceCalculated	Negative	.183	17	.135	.936	17	.277
	Positive	.192	17	.098	.922	17	.161
	Neutral	.185	17	.125	.928	17	.201

a. Lilliefors Significance Correction

### Checking for Outliers



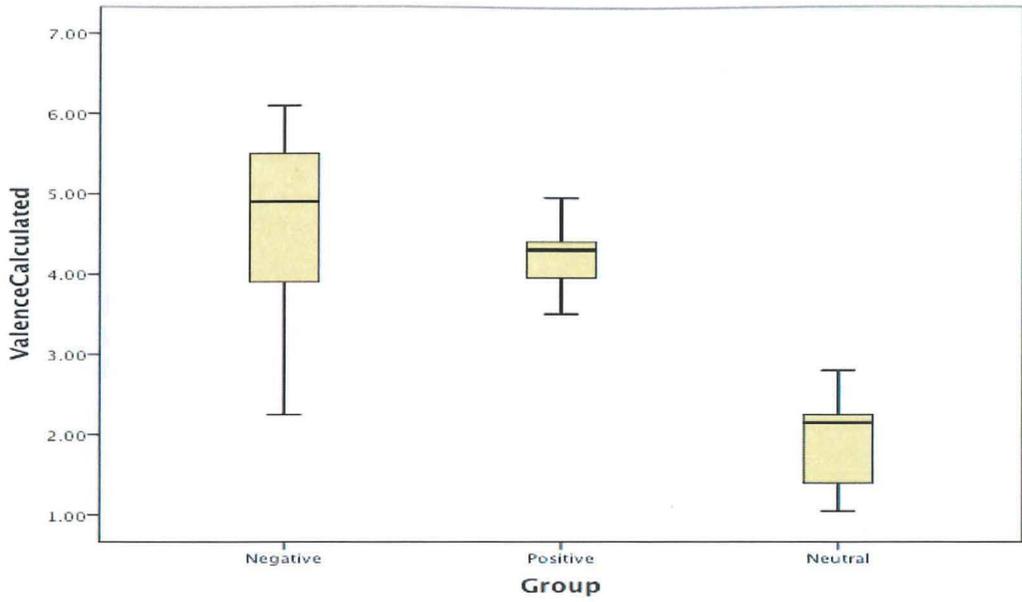
### Testing Normality Again

Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
ValenceCalculated Negative	.183	17	.135	.936	17	.277
ValenceCalculated Positive	.185	17	.125	.897	17	.060
ValenceCalculated Neutral	.185	17	.125	.928	17	.201

a. Lilliefors Significance Correction

### Checking Outliers Again



**Checking Homogeneity of Variances**

**Test of Homogeneity of Variances**

ValenceCalculated

Levene Statistic	df1	df2	Sig.
10.211	2	48	.000

**Main Analysis**

**Robust Tests of Equality of Means**

ValenceCalculated

	Statistic <sup>a</sup>	df1	df2	Sig.
Welch	87.688	2	29.587	.000

a. Asymptotically F distributed.

**Post Hoc Tests**

### Multiple Comparisons

Dependent Variable: ValenceCalculated

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Negative	Positive	.43235	.27631	.271	-.2359	1.1006
		Neutral	2.69706*	.27631	.000	2.0288	3.3653
	Positive	Negative	-.43235	.27631	.271	-1.1006	.2359
		Neutral	2.26471*	.27631	.000	1.5965	2.9329
	Neutral	Negative	-2.69706	.27631	.000	-3.3653	-2.0288
		Positive	-2.26471*	.27631	.000	-2.9329	-1.5965
Games-Howell	Negative	Positive	.43235	.30857	.358	-.3458	1.2105
		Neutral	2.69706*	.31883	.000	1.8989	3.4953
	Positive	Negative	-.43235	.30857	.358	-1.2105	.3458
		Neutral	2.26471*	.17935	.000	1.8231	2.7063
	Neutral	Negative	-2.69706	.31883	.000	-3.4953	-1.8989
		Positive	-2.26471*	.17935	.000	-2.7063	-1.8231

\*. The mean difference is significant at the 0.05 level.

### 7.2.2.4 Result of Confidence Measures

#### Tests of Normality

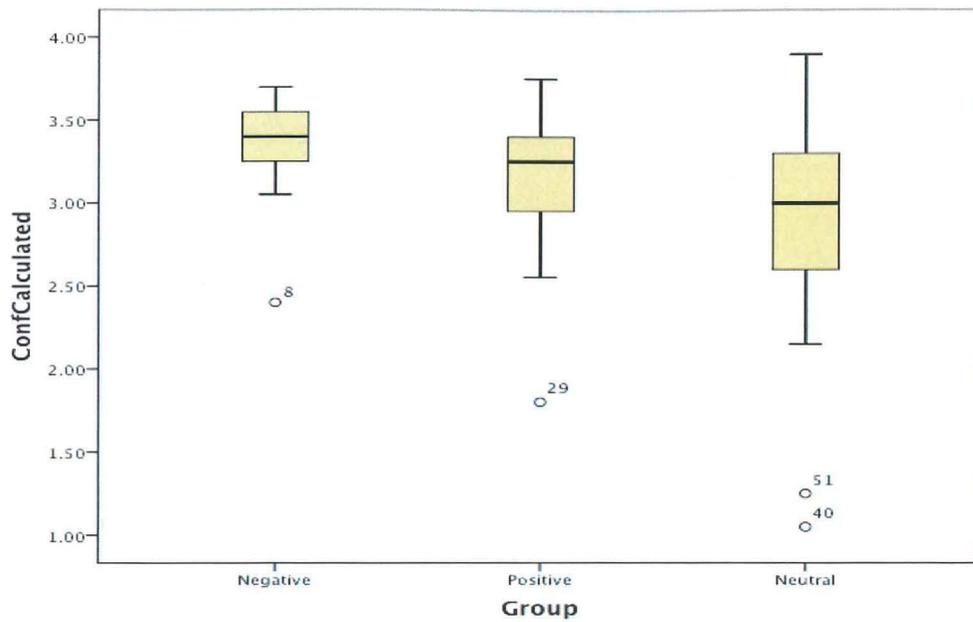
#### Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.	
ConfCalculated	Negative	.165	17	.200	.850	17	.011
	Positive	.223	17	.024	.831	17	.006
	Neutral	.186	17	.119	.900	17	.067

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

#### Checking for Outliers



### Testing Normality Again

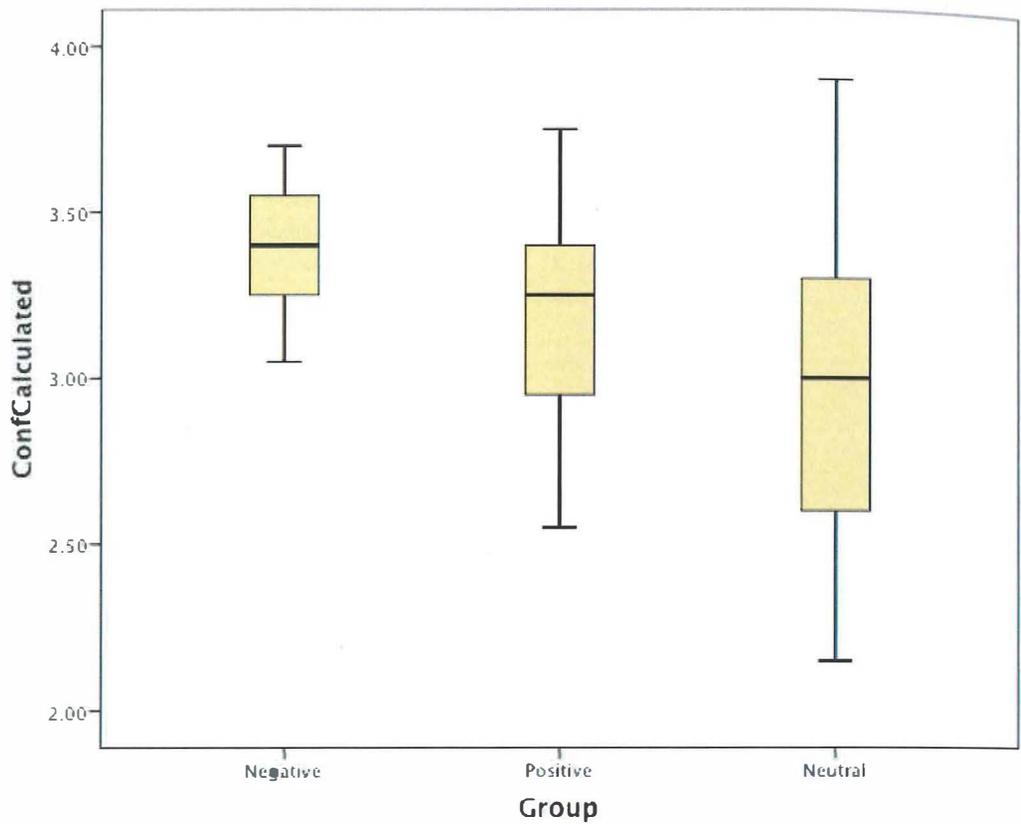
Tests of Normality

Group		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
ConfCalculated	Negative	.183	17	.133	.932	17	.239
	Positive	.184	17	.130	.935	17	.268
	Neutral	.109	17	.200 <sup>*</sup>	.960	17	.632

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking Outliers Again



**Checking Homogeneity of Variances**

**Test of Homogeneity of Variances**

ConfCalculated

Levene Statistic	df1	df2	Sig.
7.048	2	48	.002

**Main Analysis**

**Robust Tests of Equality of Means**

ConfCalculated

	Statistic <sup>a</sup>	df1	df2	Sig.
Welch	6.301	2	29.083	.005

a. Asymptotically F distributed.

## Post Hoc Tests

### Multiple Comparisons

Dependent Variable: ConfCalculated

	(i) Group	(j) Group	Mean Difference (i-j)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Negative	Positive	.20588	.12853	.255	-.1050	.5167
		Neutral	.44412*	.12853	.003	.1333	.7550
	Positive	Negative	-.20588	.12853	.255	-.5167	.1050
		Neutral	.23824	.12853	.163	-.0726	.5491
	Neutral	Negative	-.44412*	.12853	.003	-.7550	-.1333
		Positive	-.23824	.12853	.163	-.5491	.0726
Games-Howell	Negative	Positive	.20588	.09277	.085	-.0236	.4353
		Neutral	.44412*	.13745	.011	.0979	.7903
	Positive	Negative	-.20588	.09277	.085	-.4353	.0236
		Neutral	.23824	.14851	.262	-.1306	.6070
	Neutral	Negative	-.44412	.13745	.011	-.7903	-.0979
		Positive	-.23824	.14851	.262	-.6070	.1306

\*. The mean difference is significant at the 0.05 level.

7.2.2.5 Results of SA Measure

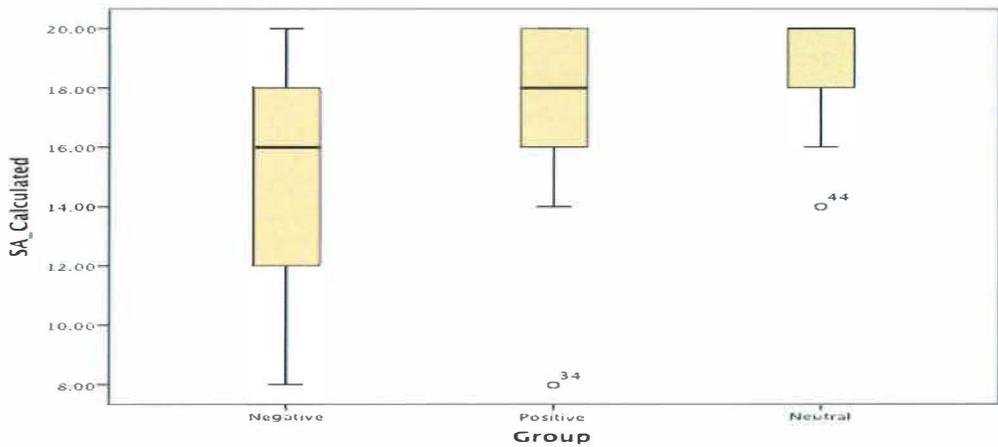
1. Tests of Normality

**Tests of Normality**

		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
SA_Calculated	Negative	.218	17	.031	.893	17	.052
	Positive	.240	17	.010	.778	17	.001
	Neutral	.303	17	.000	.742	17	.000

a. Lilliefors Significance Correction

Checking for Outliers



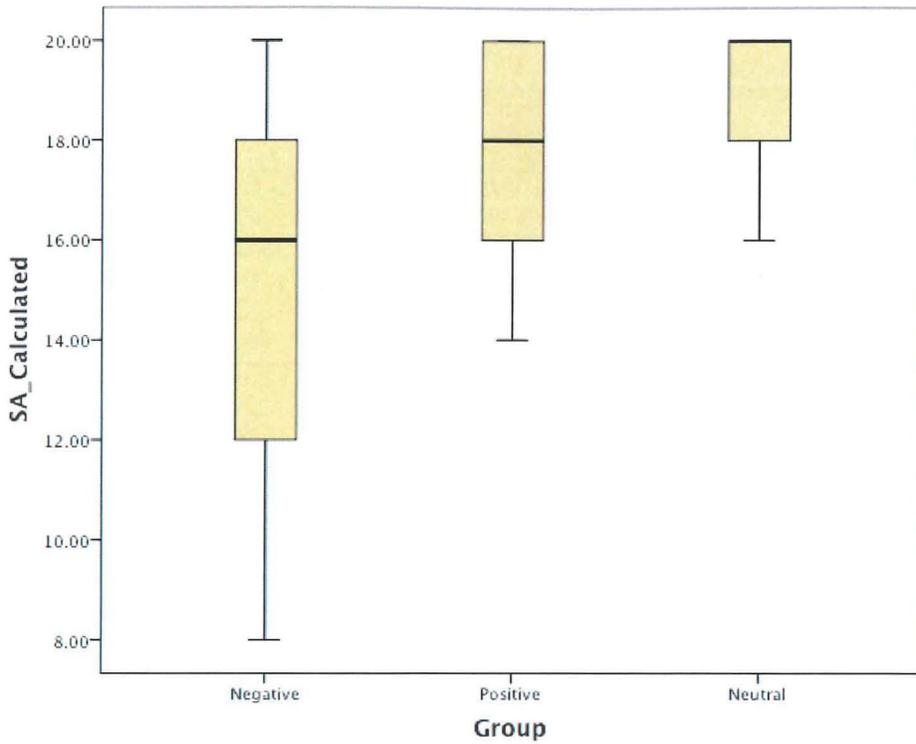
Testing Normality Again

**Tests of Normality**

		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
SA_Calculated	Negative	.218	17	.031	.893	17	.052
	Positive	.216	17	.034	.874	17	.025
	Neutral	.331	17	.000	.738	17	.000

a. Lilliefors Significance Correction

**Checking Outliers Again**



**Checking Homogeneity of Variances**

**Test of Homogeneity of Variances**

SA\_Calculated

Levene Statistic	df1	df2	Sig.
13.346	2	48	.000

**Main Analysis**

**Robust Tests of Equality of Means**

SA\_Calculated

	Statistic <sup>a</sup>	df1	df2	Sig.
Welch	7.559	2	27.870	.002

a. Asymptotically F distributed.

## Post Hoc Tests

### Multiple Comparisons

Dependent Variable: SA\_Calculated

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Negative	Positive	-2.35294*	.93194	.039	-4.6068	-.0991
		Neutral	-3.64706*	.93194	.001	-5.9009	-1.3932
	Positive	Negative	2.35294*	.93194	.039	.0991	4.6068
		Neutral	-1.29412	.93194	.355	-3.5480	.9598
	Neutral	Negative	3.64706*	.93194	.001	1.3932	5.9009
		Positive	1.29412	.93194	.355	-.9598	3.5480
Games-Howell	Negative	Positive	-2.35294	1.10049	.104	-5.1047	.3989
		Neutral	-3.64706*	1.02983	.006	-6.2633	-1.0308
	Positive	Negative	2.35294	1.10049	.104	-.3989	5.1047
		Neutral	-1.29412	.57785	.083	-2.7281	.1399
	Neutral	Negative	3.64706	1.02983	.006	1.0308	6.2633
		Positive	1.29412	.57785	.083	-.1399	2.7281

\*. The mean difference is significant at the 0.05 level.

### 7.2.2.6 Bisection Measure

#### 1. Tests of Normality

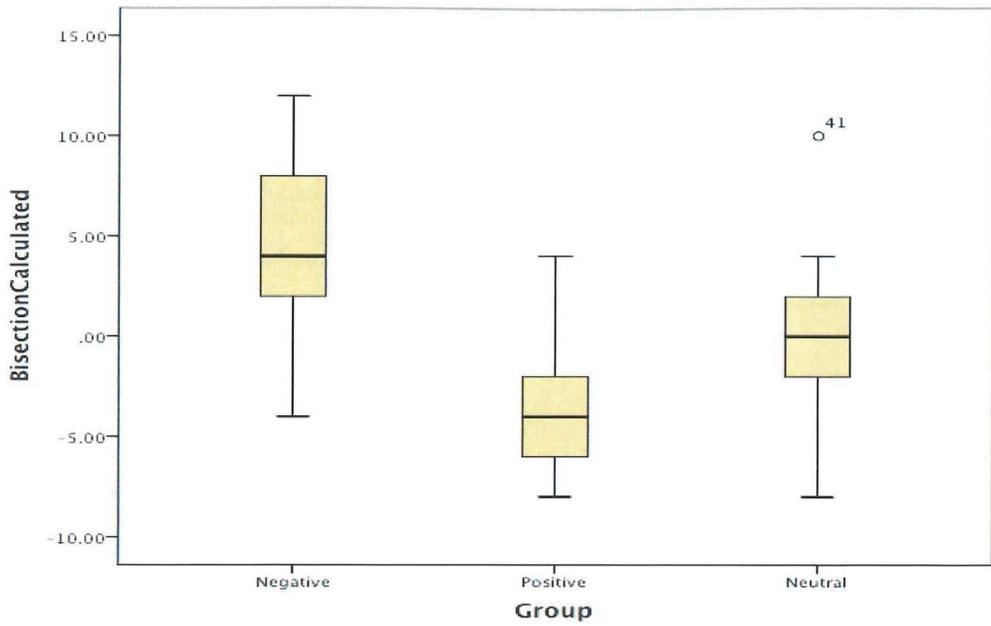
##### Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BisectionCalculated						
Negative	.117	17	.200	.958	17	.590
Positive	.225	17	.022	.886	17	.040
Neutral	.179	17	.150	.929	17	.211

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking for Outliers



### Testing Normality Again

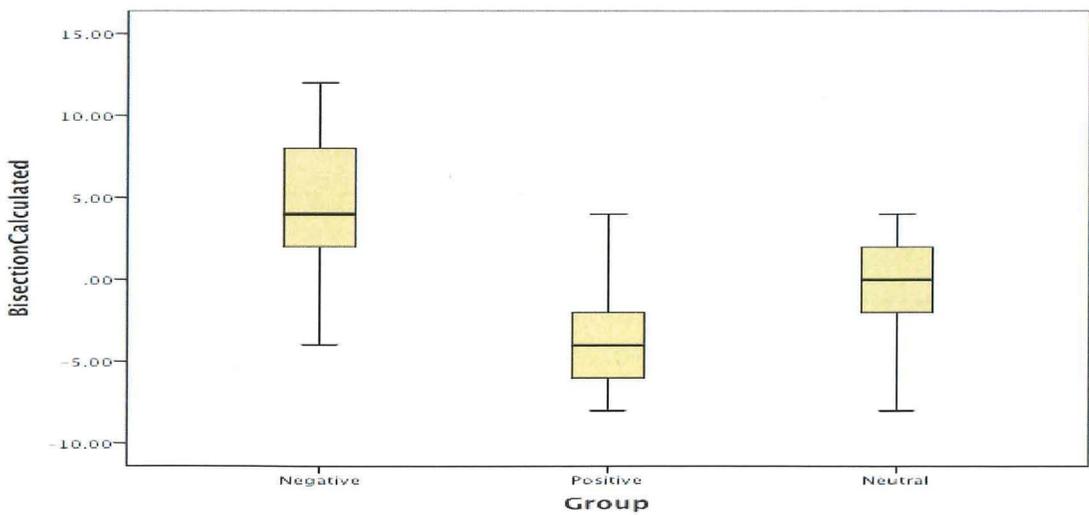
Tests of Normality

		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
BisectionCalculated	Negative	.117	17	.200	.958	17	.590
	Positive	.225	17	.022	.886	17	.040
	Neutral	.191	17	.098	.923	17	.168

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking Outliers Again



Checking Homogeneity of Variances

Test of Homogeneity of Variances

BisectionCalculated

Levene Statistic	df1	df2	Sig.
1.797	2	48	.177

Main Analysis

ANOVA

BisectionCalculated

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	539.451	2	269.725	20.274	.000
Within Groups	638.588	48	13.304		
Total	1178.039	50			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: BisectionCalculated

	(i) Group	(j) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Negative	Positive	7.88235*	1.25107	.000	4.8567	10.9080
		Neutral	4.94118*	1.25107	.001	1.9155	7.9669
	Positive	Negative	-7.88235*	1.25107	.000	-10.9080	-4.8567
		Neutral	-2.94118	1.25107	.058	-5.9669	.0845
	Neutral	Negative	-4.94118	1.25107	.001	-7.9669	-1.9155
		Positive	2.94118	1.25107	.058	-.0845	5.9669
Games-Howell	Negative	Positive	7.88235*	1.32058	.000	4.6120	11.1528
		Neutral	4.94118*	1.35102	.003	1.6028	8.2795
	Positive	Negative	-7.88235*	1.32058	.000	-11.1528	-4.6120
		Neutral	-2.94118*	1.06127	.024	-5.5498	-.3326
	Neutral	Negative	-4.94118	1.35102	.003	-8.2795	-1.6028
		Positive	2.94118*	1.06127	.024	.3326	5.5498

\*. The mean difference is significant at the 0.05 level.

### 7.2.2.7 Estimation Measure

#### 1. Tests of Normality

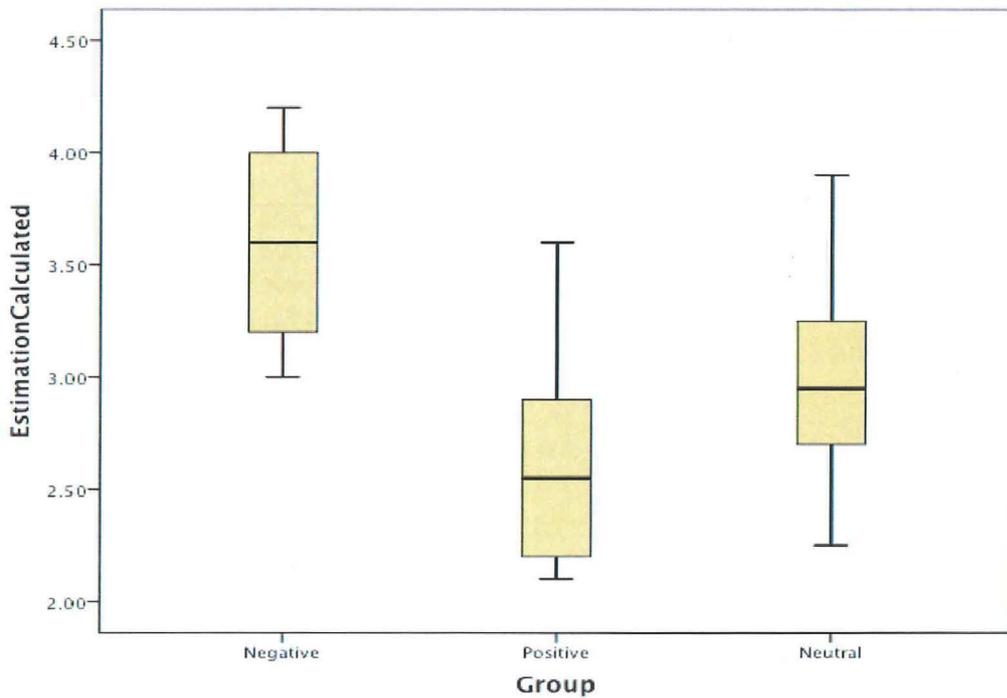
Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EstimationCalculated Negative	.215	17	.036	.874	17	.025
Positive	.126	17	.200 <sup>*</sup>	.924	17	.170
Neutral	.118	17	.200 <sup>*</sup>	.974	17	.877

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

#### Checking for Outliers



#### Checking Homogeneity of Variances

##### Test of Homogeneity of Variances

EstimationCalculated

Levene Statistic	df1	df2	Sig.
.747	2	48	.479

**Main Analysis**

**ANOVA**

EstimationCalculated

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.122	2	4.061	21.345	.000
Within Groups	9.133	48	.190		
Total	17.255	50			

**Post Hoc Tests**

**Multiple Comparisons**

Dependent Variable: EstimationCalculated

	(i) Group	(j) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Negative	Positive	.96176*	.14962	.000	.5999	1.3236
		Neutral	.63235*	.14962	.000	.2705	.9942
	Positive	Negative	-.96176*	.14962	.000	-1.3236	-.5999
		Neutral	-.32941	.14962	.081	-.6913	.0324
	Neutral	Negative	-.63235*	.14962	.000	-.9942	-.2705
		Positive	.32941	.14962	.081	-.0324	.6913
Games-Howell	Negative	Positive	.96176*	.15586	.000	.5787	1.3448
		Neutral	.63235*	.14372	.000	.2790	.9857
	Positive	Negative	-.96176*	.15586	.000	-1.3448	-.5787
		Neutral	-.32941	.14902	.085	-.6961	.0373
	Neutral	Negative	-.63235*	.14372	.000	-.9857	-.2790
		Positive	.32941	.14902	.085	-.0373	.6961

\*. The mean difference is significant at the 0.05 level.

7.2.2.6 Bisection Measure

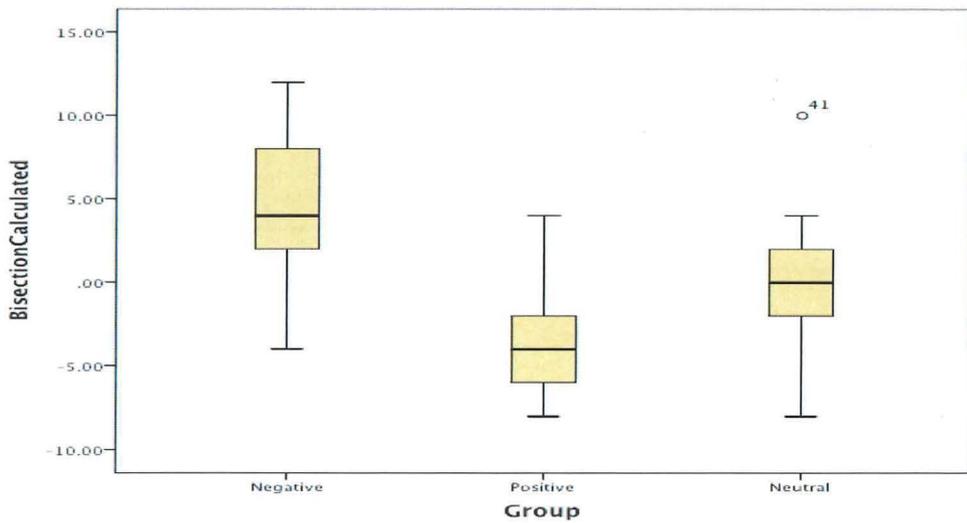
Tests of Normality

		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
BisectionCalculated	Negative	.117	17	.200	.958	17	.590
	Positive	.225	17	.022	.886	17	.040
	Neutral	.179	17	.150	.929	17	.211

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Checking for Outliers



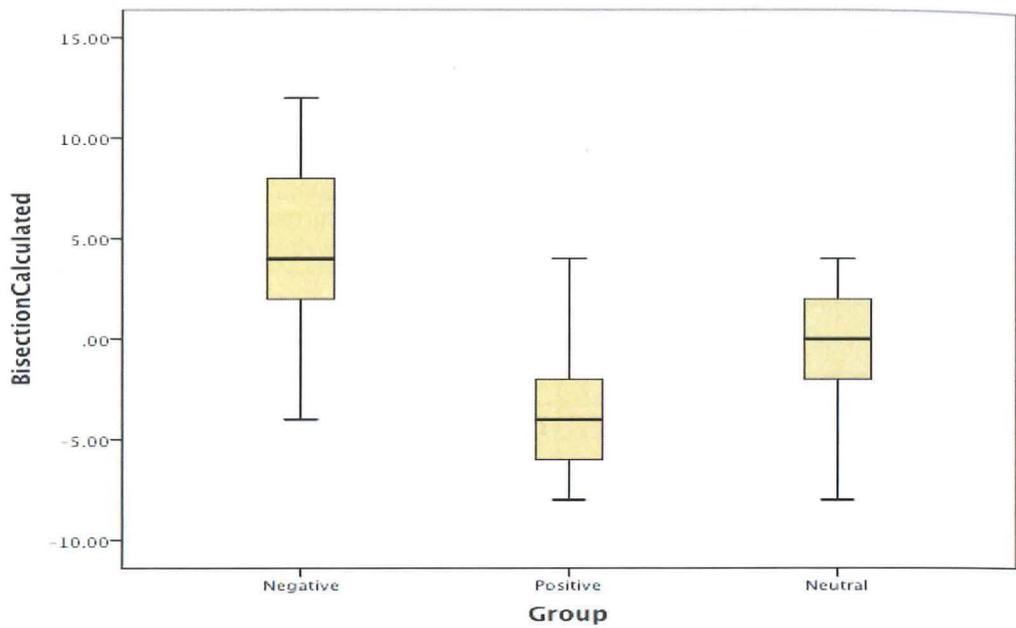
Testing Normality Again

		Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
BisectionCalculated	Negative	.117	17	.200	.958	17	.590
	Positive	.225	17	.022	.886	17	.040
	Neutral	.191	17	.098	.923	17	.168

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking Outliers Again



### Checking Homogeneity of Variances

#### Test of Homogeneity of Variances

BisectionCalculated

Levene Statistic	df1	df2	Sig.
1.797	2	48	.177

### Main Analysis

#### ANOVA

BisectionCalculated

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	539.451	2	269.725	20.274	.000
Within Groups	638.588	48	13.304		
Total	1178.039	50			

## Post Hoc Tests

### Multiple Comparisons

Dependent Variable: BisectionCalculated

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Negative	Positive	7.88235 <sup>*</sup>	1.25107	.000	4.8567	10.9080
		Neutral	4.94118 <sup>*</sup>	1.25107	.001	1.9155	7.9669
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		Neutral	4.94118 <sup>*</sup>	1.35102	.003	1.6028	8.2795
	Positive	Negative	-7.88235	1.32058	.000	-11.1528	-4.6120
		Neutral	-2.94118 <sup>*</sup>	1.06127	.024	-5.5498	-.3326
	Neutral	Negative	-4.94118	1.35102	.003	-8.2795	-1.6028
		Positive	2.94118 <sup>*</sup>	1.06127	.024	.3326	5.5498

<sup>\*</sup>. The mean difference is significant at the 0.05 level.

## 7.2.2.7 Estimation Measure

### Tests of Normality

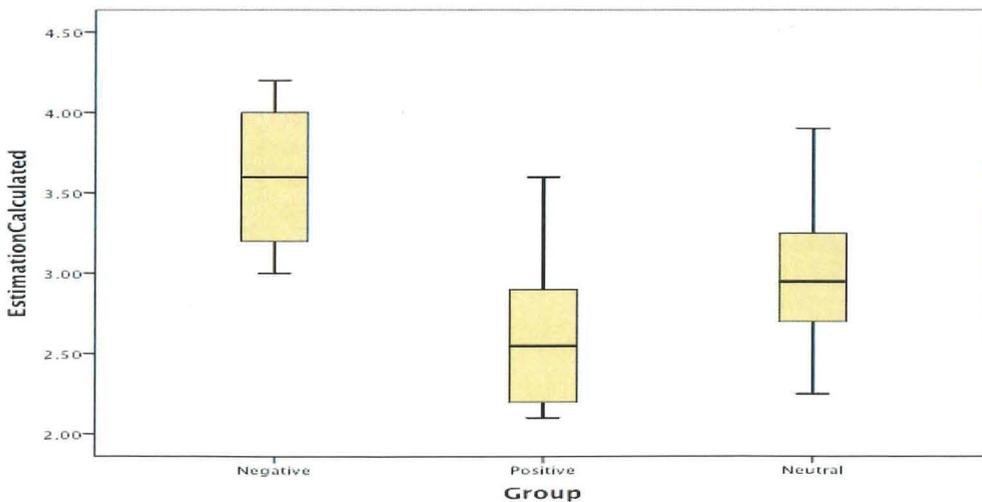
#### Tests of Normality

Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.	
EstimationCalculated	Negative	.215	17	.036	.874	17	.025
	Positive	.126	17	.200 <sup>*</sup>	.924	17	.170
	Neutral	.118	17	.200 <sup>*</sup>	.974	17	.877

<sup>\*</sup>. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

### Checking for Outliers



### Checking Homogeneity of Variances

## Test of Homogeneity of Variances

EstimationCalculated

Levene Statistic	df1	df2	Sig.
.747	2	48	.479

### Main Analysis

#### ANOVA

EstimationCalculated

	Sum of Squares	df	Mean Square	F	Sig.
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### Post Hoc Tests

#### Multiple Comparisons

Dependent Variable: EstimationCalculated

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
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		Neutral	.63235*	.14962	.000	.2705	.9942
	Positive	Negative	-.96176	.14962	.000	-1.3236	-.5999
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	Neutral	Negative	-.63235	.14962	.000	-.9942	-.2705
		Positive	.32941	.14962	.081	-.0324	.6913
Games-Howell	Negative	Positive	.96176*	.15586	.000	.5787	1.3448
		Neutral	.63235*	.14372	.000	.2790	.9857
	Positive	Negative	-.96176	.15586	.000	-1.3448	-.5787
		Neutral	-.32941	.14902	.085	-.6961	.0373
	Neutral	Negative	-.63235	.14372	.000	-.9857	-.2790
		Positive	.32941	.14902	.085	-.0373	.6961

\*. The mean difference is significant at the 0.05 level.

Chapters 8 and 9 went through similar analysis

## APPENDIX B

Below are the Consent Forms and Information Sheets Given to Participants for each Chapter.

## Chapter 2

### **PARTICIPANT INFORMATION SHEET**

Please, continue only if you **do not have** any history of emotional disturbance or heart condition.

## Effects of Emotional Arousal on Situational Awareness

We would like to invite you to participate in this research project being undertaken by Mr Dritan Nikolla. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. If you would like to take part, please let us know if you have been involved in any other study during the last year.

The research project is a study about how individuals' awareness of a situation changes according to their emotional state and how this affects memory and cognitive performance. You will be asked to complete a questionnaire (measuring aspects of your current emotional state), then look at a series of pictures, some of which may be **explicit** in nature or **emotionally disturbing**. For this reason those who have suffered from an anxiety disorder, depression or a heart condition may not take part. If you wish to see examples of the photos before deciding whether to participate, please ask the investigator.

Following this you will be asked to participate in an "enemy detection" computer task, which involves the presentation of photos sampled from video recording of a war-game (see the photo 1 below).

Sample Photo of War-game Task



Photo 1

You will be asked to take control of a robot that is located remotely at the battlefield. The task requires you to learn what the controlling levers do, and in addition you will be asked questions from the army's headquarters (HQ). The task is not timed but you are expected to complete the task as quickly as you can do so, without compromising performance.

Your participation is expected to last around 30 minutes.

Detailed instructions will however, be given at each stage of the experiment via the computer screen. You will be given an opportunity to practice the tasks and to ask any question you may have before you start.

Further details of the task and the rationale behind it will be provided in the debrief session, at the end of the study.

You may at any time withdraw from the study without giving a reason. If you ever require any further explanation, please do not hesitate to ask.

Any information obtained during this trial will remain confidential as to your identity: if it can be specifically identified with you, your permission will be sought in writing before it will be published. Other material, which cannot be identified with you, will be published or presented at meetings with the aim of benefiting others. You may ask the Project Officer for copies of all papers, reports, transcripts, summaries and other published or presented material. All information will be subject to the current conditions of the Data Protection Act 1998.

Experimental records, including paper records and computer files, will be held for a minimum of 10 years in conditions appropriate for the storage of personal information. You have right of access to your records at any time.

Name and contact details of Principal Investigator:

Mr Dritan Nikolla

E-mail: [dnikolla@glos.ac.uk](mailto:dnikolla@glos.ac.uk)

Tel:01242714844

## CONSENT FORM FOR ALL EXPERIMENTS

**Title of Study:** Effects of Emotional Arousal on Situational Awareness

The nature, aims and risks of the research have been explained to me. I have read and understood the Participant Information Sheet and understand what is expected of me. All my questions have been answered fully to my satisfaction.

I understand that if I decide at any time during the research that I no longer wish to participate in this project, I can notify the researchers involved and be withdrawn from it immediately without having to give a reason.

I understand that the screening process to decide if I am suitable to be selected as a participant may include completing a medical screening questionnaire and/or a physical examination by a medical officer and I consent to this.

I consent to the processing of my personal information for the purposes of this research study. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

I agree to volunteer as a participant for the study described in the information sheet and give full consent.

This consent is specific to the particular study described in the Participant Information Sheet attached and shall not be taken to imply my consent to participate in any subsequent study or deviation from that detailed here.

### ***Participant's Statement:***

I \_\_\_\_\_

**agree that the research project named above has been explained to me to my satisfaction and I agree to take part in the study. I have read both the notes written above and the Participant Information Sheet about the project, and understand what the research study involves.**

**Signed**

**Date**

**Witness**

**Name**

**Signature**

### ***Investigator's Statement:***

I \_\_\_\_\_

**confirm that I have carefully explained the nature, demands and any foreseeable risks (where applicable) of the proposed research to the Participant.**

**Signed Date**

### **AUTHORISING SIGNATURES**

**The information supplied above is to the best of my knowledge and belief accurate. I clearly understand my obligations and the rights of research participants, particularly concerning recruitment of participants and obtaining valid consent.**

***Signature of Principal Investigator***

**Date**

***Name and contact details of Principal Investigator:***

Name and contact details of Principal Investigator:

Dritan Nikolla

E-mail: [dritannikolla@connect.glos.ac.uk](mailto:dritannikolla@connect.glos.ac.uk)

Tel: 01242 714807

## **Debriefing Form for Military Task**

This study was designed to examine the way in which people process ambiguous information as true or false under different emotional conditions.

The data collected on this study is used to investigate a new model of Situation Awareness, which means, knowing what is going on around you. The purpose of our model is to detect people that are likely to make an error, such as friendly fire, and develop strategies to neutralize them.

I hope that this has helped to clarify for you the purpose of the study you have just undertaken.

If you have any further questions or feel that you need to talk to someone about your participation please contact Dritan Nikolla (**Email:** [dritannikolla@connect.glos.ac.uk](mailto:dritannikolla@connect.glos.ac.uk); **Mobile:** 07823322559) or Dr. Graham Edgar ([gedgar@glos.ac.uk](mailto:gedgar@glos.ac.uk))

If you feel you need further help, please use University of Gloucestershire Counseling Service:

*Links to the University of Gloucestershire Counseling service and Phone Number:*

**Website:** <http://resources.glos.ac.uk/departments/student-services/counselling/> **Phone:** 01242 714542

**You participation in this study is greatly appreciated**

**Chapter 4 to 6 only the CONSENT form was used.**

Chapter 7, 8 and 9 all used the following information sheet. The same consent form as before was used.

## PARTICIPANT INFORMATION SHEET

Please, continue only if you **do not have** any history of emotional disturbance or heart condition.

### Effects of Emotional Arousal on Situational Awareness as reflected in Time Perception and Somatic Markers.

MoDREC reference number:

We would like to invite you to participate in this research project being undertaken by Mr Dritan Nikolla. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. If you would like to take part, please let us know if you have been involved in any other study during the last year.

The research project is a study about how individuals' feeling of time changes according to their emotional state and how this affects memory and cognitive performance. You will be asked to complete three questionnaires (measuring aspects of your current emotional state), then look at 90 pictures, some of which may be **explicit** in nature or **emotionally disturbing**. For this reason those who have suffered from an anxiety disorder, depression or a heart condition may not take part. If you wish to see examples of the photos before deciding whether to participate, please ask the investigator.

Your participation is expected to last around 45 minutes.

Detailed instructions will however, be given at each stage of the experiment via the computer screen. You will be given an opportunity to practice the tasks and to ask any question you may have before you start.

Further details of the task and the rationale behind it will be provided in the debrief session, at the end of the study.

You may at any time withdraw from the study without giving a reason. If you ever require any further explanation, please do not hesitate to ask.

Any information obtained during this trial will remain confidential as to your identity: if it can be specifically identified with you, your permission will be sought in writing before it will be published. Other material, which cannot be identified with you, will be published or presented at meetings with the aim of benefiting others. You may ask the Project Officer for copies of all papers, reports, transcripts, summaries and other published or presented material. All information will be subject to the current conditions of the Data Protection Act 1998.

In the event of you suffering any adverse effects other than emotional disturbance as a consequence of your participation in this study, you will be eligible to apply for compensation under the MoD's 'No-Fault Compensation Scheme' (see details attached).

Experimental records, including paper records and computer files, will be held for a minimum of 10 years in conditions appropriate for the storage of personal information. You have right of access to your records at any time.

Participants' travel expenses will be reimbursed.

A full scientific protocol for this research has been approved by the Ministry of Defence Research Ethics Committee. This study complies and at all times will comply with the Declaration of Helsinki<sup>5</sup> as adopted at the 52nd WMA General Assembly, Edinburgh, October 2000 and with the Additional Protocol to the Convention on Human Rights and Biomedicine, concerning Biomedical Research, (Strasbourg 25.1.2005). Please ask the Project Officer if you would like further details of the approval or to see a copy of the full protocol.

Name and contact details of Principal Investigator:

Mr Dritan Nikolla

e-mail: [s0712633@connect.glos.ac.uk](mailto:s0712633@connect.glos.ac.uk)

[Tel:01242714844](tel:01242714844)

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<sup>5</sup> World Medical Association (2000) Declaration of Helsinki. Ethical principles for medical research involving human subjects. 52<sup>nd</sup> World Medical Association General Assembly, Edinburgh, Scotland October 2000.