Visual Patterns in the Perception of Abstract and Social Stimuli

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Abstract

This thesis investigated with regard to the perception of abstract and social stimuli: (1) What constitutes a visual pattern? (2) Whether people possess a proclivity towards one particular pattern type. (3) When is patterning imposed or detected by the visual system? The abstract stimuli consisted of checkerboard patterns and the social stimuli consisted of faces or social groups. Initially the term "pattern" was defined as an image that contains redundant information. This was illustrated by a bias when defining patterns by members of the public towards images that contain both repeated and reflective symmetry, or a low number of possible variants and therefore reduced information content, i.e. more redundancy. Similarly reflective symmetry was identified as a key property in defining faces. The effect of symmetry type on early visual processing was investigated further in a series of backward masking experiments on both abstract and facial stimuli (Chapters 6 & 7). The results of the masking experiments suggest a bias during early visual processing for patterns that contain symmetry (i.e. repetition or reflection), or share common fate compared with randomly generated patterns or distorted faces. A top-hemifield and LVF bias was observed in the early detection of patterns. Patterns that take advantage of these properties such as the eyes within the face were suggested as having a perceptual advantage.

Patterning appears to be imposed at all stages of visual processing. At early stages of visual processing, repetition (and in the face the eyes) was observed as having an early perceptual advantage over reflection (and in the face the mouth). However at later stages of processing repetition appeared to be processed serially and no longer had a perceptual advantage over reflection (ISIs >42ms). Reflection was suggested as having a perceptual advantage post V1 (ISIs >96ms). Patterning continues throughout a visual scene from the local level to the global level, as such both the human face and human social groups can be perceived as patterns. This was illustrated by a series of experiments investigating the effect of patterning on the perception of images presented in the periphery of a scene (Chapter 8).

Author's Declaration

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 1 - 02 - 06 ....

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Chapter 1: Patterns and symmetry

1.1 Bias of human visual system to visual pattern

Humans have a predisposition to organise and make sense of their environment. It is therefore no surprise that the visual system possesses the ability to extract and interpret patterns from the visual world (Barlow, 1972; Engel, Fries, König, Brecht & Singer, 1999; Hubel & Wiesel, 1977; Singer & Gray, 1995). Any given image comprises of a number of local contrast borders based upon luminance, orientation and wavelength. For any one object to be identified from within a visual scene these borders have to be integrated and segregated from the other background elements. The possible combinations of featural elements that are detected by the visual system are virtually unlimited. However, when confronted with a new scene the visual system has little problem breaking down the image into its component parts with the minimum of cortical processing. One way in which the visual system can solve the problem of sorting out the information presented within the visual world is via rapid identification of specific "patterns".

At the most basic level, neurons in the visual cortex have been shown to respond to the basic Fourier components into which the stimulus can be decomposed (Blakemore & Campbell, 1969; Campbell & Robson, 1988). On the other hand, at a higher level, the visual stimulus may be processed in terms of visual patterning (Herrmann & Bosch, 2001; Kovacs, Feher & Julesz, 1998; Kurylo, 1997; Oka & Ejima, 2001). The term "pattern" is used in various ways in regard to visual processing, but all encompass the concept that the component features of the visual stimulus are grouped or organized in some fashion (see Chapter 3 for further definition of patterns). One of the primary factors underlying such organization is the degree of redundancy or consistency within these components. Such redundancy can occur as the result of symmetry (i.e. repetition and reflection) within the constituent elements of an image. Consistency or redundancy within these components can be achieved via identification of the axes of reflection and repetition in order to create meaningful shapes from otherwise random boundary contours (Kovacs et al., 1998; Van Tonder & Ejima, 2000). The visual system appears to be able to register such similarities and use them as a basis for ordering, grouping, organizing and categorizing the visual flux in such a way that "patterns" can be identified within the visual stimulus (see Section 1.2).

The extraction of visual pattern may be such a potent tendency that the visual system may even impose patterning on spatially random visual stimuli under some circumstances (Falk, 1991). This behaviour was illustrated in a series of experiments where participants were asked to rate checkerboard grids in terms of which were the most or least random (Falk, 1991; Falk & Konold, 1997). The participants attempted to mentally encode randomness in accord with their own preconceptions and therefore perceived a random grid of black and white squares to contain more evenly spaced elements than chance alone would allow. This suggests that even in our perceptions of randomness there is still an attempt to impose order on the task and therefore regularity Truly random displays would contain sparsely distributed and clustered elements in a non-predictable spatial distribution. However, even in truly random arrays there is a tendency to focus on the clustered elements as being intentional groups and attributing meaning to them (Wolfram, 2002). This suggests that the human visual system has evolved to detect patterns within the environment.

There may be a strong benefit of being able to extract patterns from the visual stimulus in terms of being able to reduce the processing load and enhance processing time, enabling more rapid identification of stimuli. Once a pattern is identified, it may not be necessary to process all parts of the pattern, only enough information to confirm that it *is* a pattern. Therefore the human visual system might possess biases towards different types of patterning, specifically those that are encountered frequently within the visual world.

Despite the importance of this response to pattern by the visual system, there are many aspects of this capacity that have yet to be explored. One key issue is whether patterning involves early phases of visual processing or requires subsequent higher-order processing. Even in regard to simple, well-defined patterns (such as checkerboards), there is no clear consensus on this question (Victor, Conte, Purpura & Katz, 1995; Mancini, Sally & Gurnsey, 2005). This issue is even less resolved in regard to visual patterns that are more ecologically valid and relevant. For example, it has not been determined whether the patterned elements in human faces are perceived according to the same fundamental principles and by means of the same essential visual mechanisms as more abstract patterns. This thesis addresses these concerns. The issues of what constitutes a visual pattern and when patterning is imposed or detected by the visual system will be examined in regard to both abstract patterns and patterns with higher ecological relevance, i.e. human faces and human social groupings.

1.2 Pattern as a tool in visual "information" processing

For the human brain to make sense of visual information it has to be able to interpret and categorise the input. In order to do this the brain has to be able to pick up on perceptual units and understand how these units interact with each other to form textures, objects and groups. By being sensitive to predefined perceptual elements the visual system can rapidly process and act upon information without excessive reliance on labour intensive analysis of a scene. One of the ways visual information can be sorted is by examining simple rules that predict whether a set of characteristics are part of an object or part of background noise and patterning may be an important tool in this regard.

From this frame of reference, the term "information" is not used with reference to the meaning of an object but with reference to the average level of entropy within a system (Aleksander, 2002; Casti, 2000; Shannon, 1948; Weaver, 1963). In other words information is a measure of the randomness or the surprise within a system. For example, if a friend imparted some personal secret to another friend then the information contained in that message, or the surprise, would be high. However, if the receiver of the information already knew the secret, then there would be no surprise, the information content would be low. The information contained within the optic array is very large, and the visual system has to filter this information to make sense of the environment around it. In order to do this the visual system may take advantage of redundant information. Information redundancy refers to the fraction of the message that is unnecessary or that holds no surprises (Weaver, 1963). Within the visual array there is noise or interference from competing images, and redundancy can help to register this information without the need to serially analyse every single detail. Patterns, by definition, contain redundant information and therefore are a useful tool in rapidly processing visual information.

Redundancy provides a useful method in assessing the salience of pattern types and for analysing how perceptual elements are perceived as being part of a perceptual whole. For example patterns that comprise proximate repeated elements might be perceived as being part of a whole as the properties of each individual element become irrelevant. The concept of goodness of form, the tendency towards regularity and symmetry within a stimulus, as proposed by the Gestalt school of psychology (Koffka, 1935; Wertheimer, 1912) is one such method of finding redundancy within the optic array. These ideas have since been combined with information theory (Olson & Attneave, 1970) and applied to representational and process based theories to provide explanations for how different pattern types are perceived. Two ways of analysing how patterns are perceived include process based and representational theories. Process based theories examine the physical processes that are involved in the identification of different visual patterns and are based on observable psychophysical and neurological evidence. Representational theories are focused primarily on the properties of the visual stimuli that are being perceived and the computational way in which these might be reinterpreted by the visual system. The following section considers representational theories of figural goodness and simplicity with regard to pattern perception and the effects this can have on information redundancy (Process theories are reviewed in section 1.4)

1.3 Representational theories of figural goodness and simplicity

In the 1920s the Gestalt psychologists proposed several laws of organisation based upon identifying patterns and groupings between visual elements (Koffka, 1935; Wertheimer, 1912: see Figure 1.1). Certain arrangements were perceived as being stronger than others and therefore providing good form, which they termed Prägnanz. The laws include the "*law of proximity*" whereby those elements that are situated close to each other are grouped together. The "*law of similarity*" where elements that share similar properties such as shape, colour, orientation or texture are grouped together (Olson & Attneave, 1970). According to the "*law of closure*", missing parts of a figure are filled in to create a complete the figure. The "*law of good continuation*" suggests that perceptual organisation will tend to preserve smooth contours rather than abrupt angular changes. Finally, the "*law of common fate*" suggests that repeated elements that move together will tend to be perceived together (Gibson, Gibson, Smith & Flock, 1959).

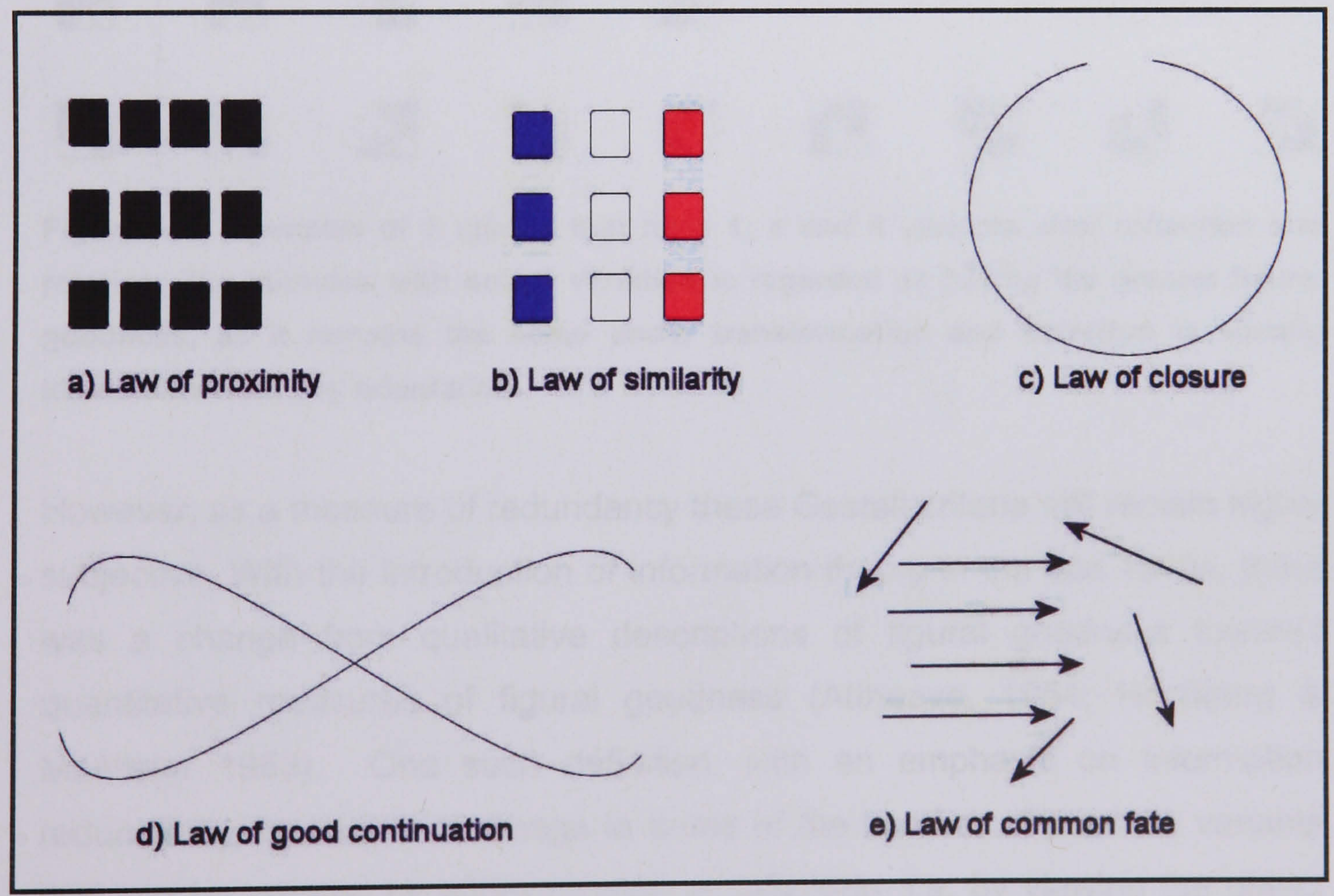


Figure 1.1: Examples of the Gestalt laws of organisation.

The Gestalt psychologists proposed that these laws reflect innate basic organisational processes within the brain, however some "cognitive" psychologists have tended to argue that these laws are the product of experience (Eysenck & Keane 1990; Marr, 1982). Despite the subjective nature of the categories chosen by the Gestalt school, the laws they proposed provide a useful description of principles for filtering out information from the optic array and therefore reducing the information load on the visual system. The laws of Prägnanz can be observed in a variety of stimuli. For example within the face the eyes can be perceived as being grouped by the law of similarity and proximity. Their shape can be described in terms of the law of closure and the way they move in terms of common fate. Thus these principles may describe why facial features are perceived as grouped or organised patterns and not as disparate floating features.

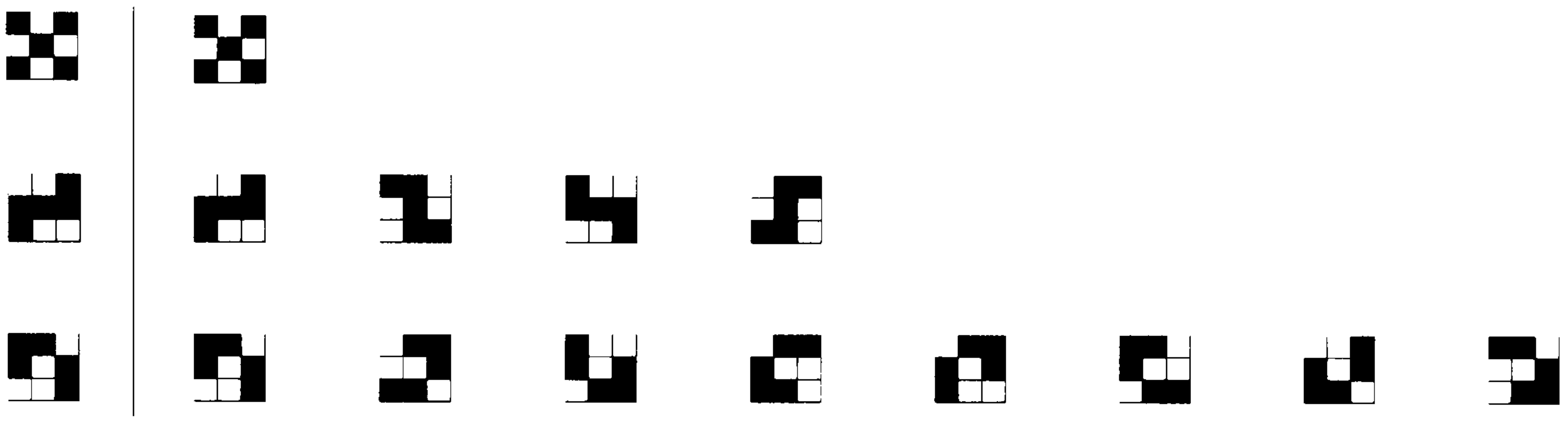


Figure 1.2: Examples of 3 stimuli that have 1, 4 and 8 variants after reflection and rotation. The stimulus with only 1 variation is regarded as having the greater figural goodness, as it remains the same under transformation and therefore is equally identifiable from any orientation.

However, as a measure of redundancy these Gestalt criteria still remain highly subjective. With the introduction of information theory in the late 1940s, there was a change from qualitative descriptions of figural goodness towards quantitative measures of figural goodness (Attneave, 1954; Hochberg & McAlister 1953). One such definition, with an emphasis on information redundancy, considers an image in terms of the number of possible variants that can be created by either rotation or reflection, i.e. by viewing the object from a different orientation or by mirroring the image (Attenave, 1954; Handel & Garner, 1965: see Figure 1.2). A pattern with a low number of variants or high redundancy, i.e. one that does not alter when reflected or rotated, requires minimal interpretation under transformation and therefore can be considered to require the processing of less information compared to a pattern with a high number of variants (Figure 1.2). Patterns that possess multiple lines of reflective symmetry will therefore have higher figural goodness, as they will have fewer possible variations when reflected or rotated and therefore require the processing of less information.

The theories of Hochberg and McAlister (1953) and Attneave (1954) provided a basis for the analysis of pattern types in terms of reflective symmetry as a method of reducing information. However, the theories do not take into account the other major symmetry type, repetition, and how the properties of repeated stimuli could affect the information processing of visual patterns. As symmetry type has now been identified as being a property that can be associated with a reduction in the information contained within a pattern, it is necessary to clarify what is meant by the term symmetry.

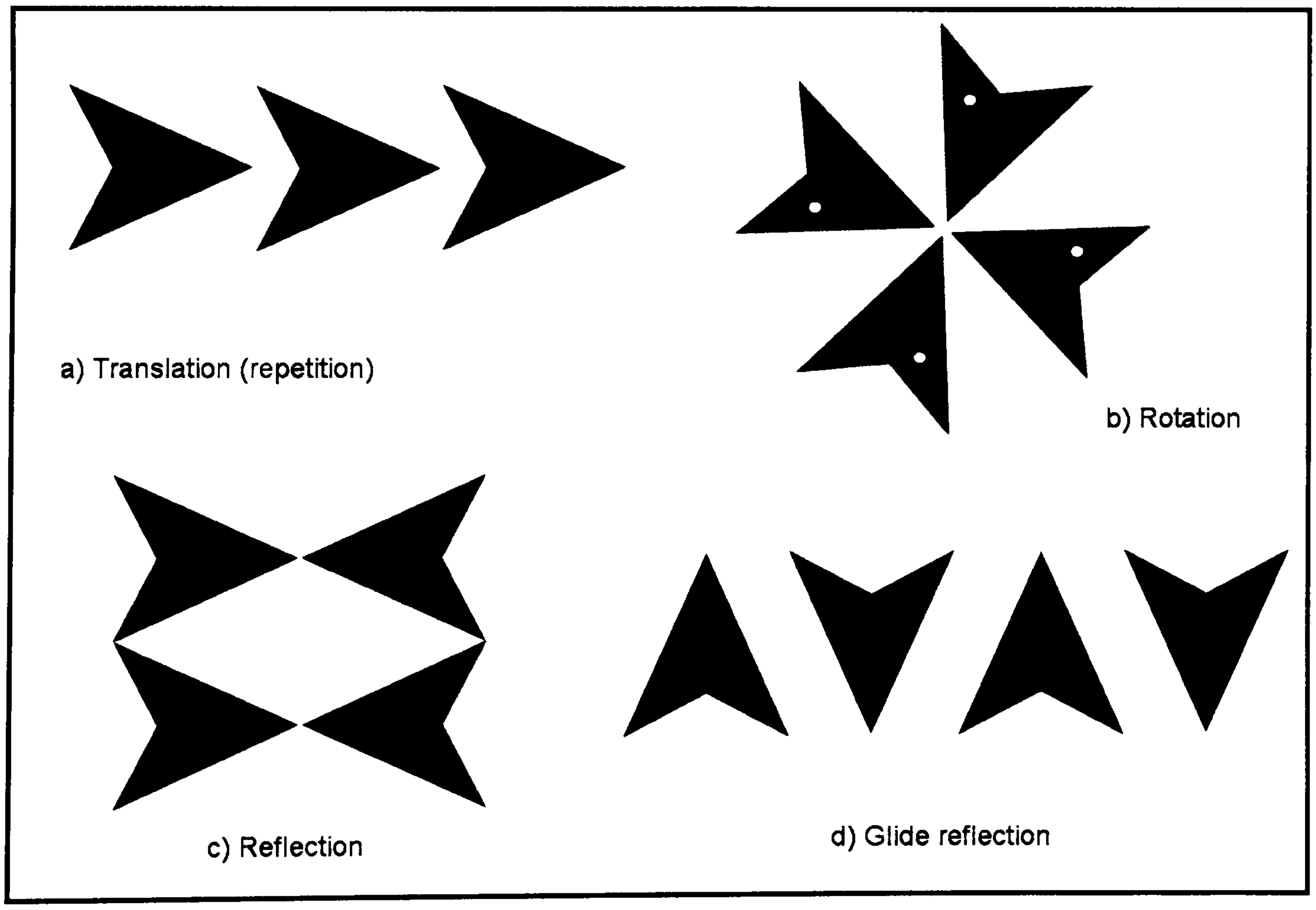


Figure 1.3: Examples of the direct symmetries, translation (repetition) and rotation; and the indirect symmetries, reflection and glide reflection.

The term symmetry is frequently misused in psychological literature, often referring only to bilateral or mirror symmetry (Wagemans, 1995). However, symmetry, according to Euclidean geometry, refers to self-similarity under a class of transformations. The basic transformations can be subdivided into two symmetry groups, the direct and indirect symmetries. The direct symmetries are repetition and rotation, and the indirect symmetries are reflection and glide reflection, i.e. reflection combined with translation (Figure 1.3). For the purpose of this study, two types of symmetry will be examined in detail; these being reflective symmetry and repetition. These two particular symmetry types were selected as they provide the basis for many recent studies of both representational and process based theories of pattern perception. The type of symmetry can have a profound effect on the figural goodness of a pattern in terms of representational theories. Three representational models that analyse the pattern structure for reflection and repetition using a computational approach are discussed in the following section.

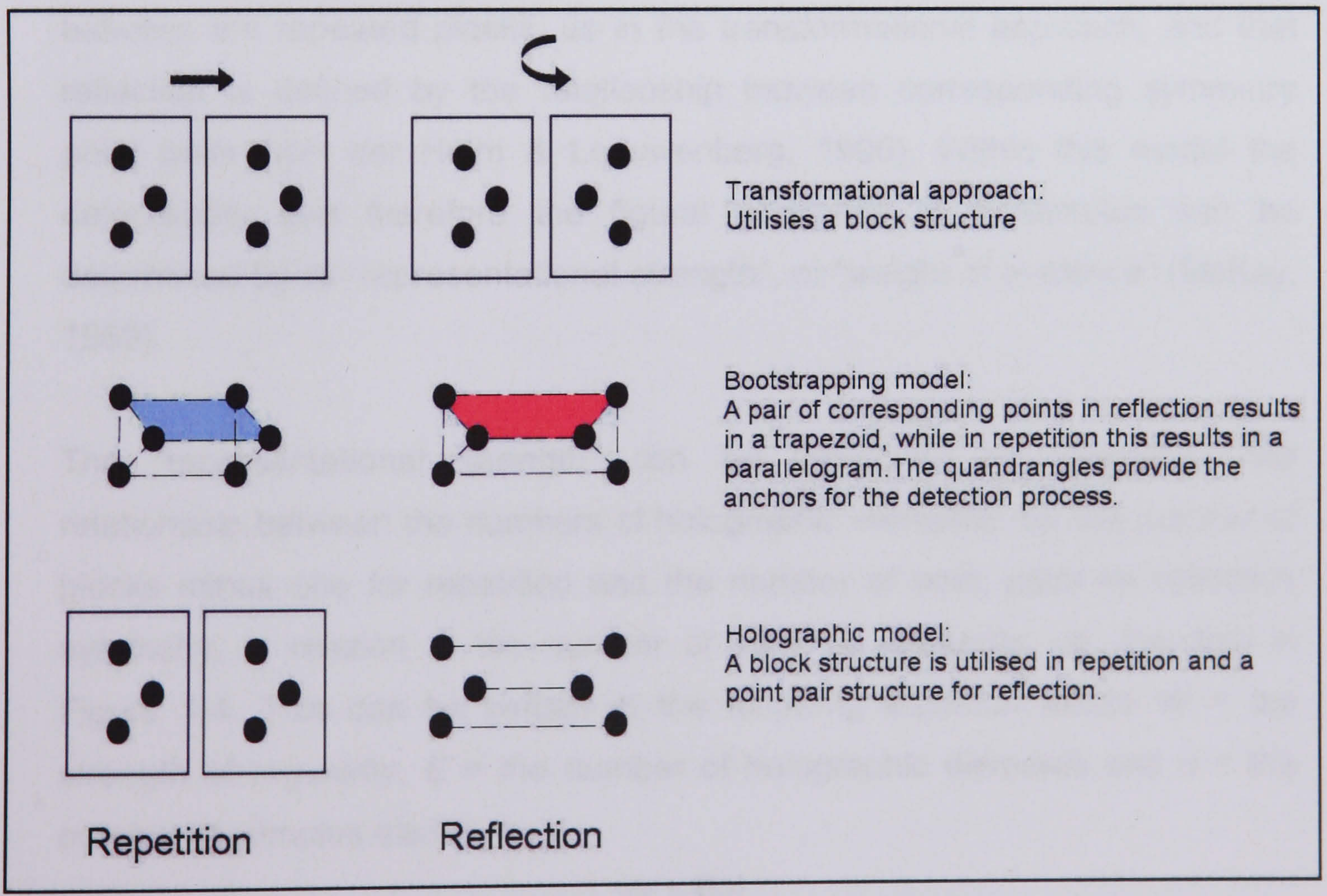


Figure 1.4: Three theories for the differential perception of reflection and repetition: the transformational, Bootstrap and holographic model.

Three of the most widely applied models used to analyse differences between symmetry types are the transformational model (Garner, 1974; Palmer, 1983), the bootstrapping model (Wagemans et al., 1993) and the holographic model (van der Helm & Leeuwenberg, 1991, 1996; van der Vloed, Csathó, & van der Helm, 2005). The transformational models examine repetition and reflection in terms of a block structure where the units are reflected or repeated as a whole unit. This model is based on classical geometry. However the transformational approach although descriptive, does not account for the structural differences within the resulting patterns. The bootstrapping model examines the resulting patterns in terms of a point structure, where the elements that constitute the pattern are examined in relation to each other (Wagemans, van Gool, Swinnen & van Horebeek, 1993). The complexity of the patterns can be reinterpreted in terms of the formation of quadrangles between groups of element pairs (Figure 1.4). This method provides a more quantitative description of the patterns in terms of individual pattern properties and the detectability of visual regularity within a pattern. The holographic model assumes that representationally, repetition is defined by relationships between the repeated blocks, as in the transformational approach, and that reflection is defined by the relationship between corresponding symmetry point pairs (van der Helm & Leeuwenberg, 1996). Within this model the detectability and therefore the figural goodness of a stimulus can be determined by its "representational strength", or "weight of evidence" (McKay, 1969).

The "representational strength" can be calculated by examining the relationship between the numbers of holographic elements, i.e. the number of blocks minus one for repetition and the number of point pairs for reflective symmetry, in relation to the number of stimulus elements, i.e. the dots in Figure 1.4. This can be written in the following equation where W = the strength of regularity, E = the number of holographic elements and n = the number of stimulus elements.

$$W = E/n$$

In terms of figural goodness the holographic model gives reflection an advantage over repetition that is not present in the transformational approach (see section 5.2 for a worked example). The representation of repetition will always be dependent upon the number of repeats while reflection is dependent on the pairing of points. Therefore in an example where both repetition and reflection are constructed on the same initial units and contain the same number of stimulus elements, reflective symmetry will be the most detectable because the ratio between the holographic elements and stimulus elements will be greater for the reflected condition compared to the repeated condition (van der Helm & Leeuwenberg, 1991; 1996). However, Porthos and Ward (2000) highlight certain conditions utilising the weight of evidence method and the holographic model where the calculated advantage for reflection over repetition are not replicated experimentally. Participants were asked to identify as rapidly as possible which of two dot sequences contained a violation in regularity. The regularities in the dot sequences were either repetitive or reflective in nature and a fast reaction time was equated with greater representational strength within the sequence. The results suggest that under certain conditions repetition can be regarded as containing greater representational strength than reflection. These conditions were when the reflected stimuli contained more element types than the repetitive stimuli or when the reflective elements were mirrored across a large range, i.e. there is a large distance between point pairs. Despite these findings the weight of evidence method provides data that is empirical and testable, even if the results do not necessarily support the initial conclusions put forward by the holographic model.

As demonstrated by the studies of Porthos and Ward (2000) the complexities of the patterns can influence the resulting figural goodness. Simplicity benefits perception in that simple descriptions, i.e. those that require less information or possess greater redundancy, are easier to detect within noise (Chater, 1996; Chater & Vitanyi, 2003; Hochberg & McAlister, 1953; van der Helm & Leeuwenberg, 1996). The simpler the stimulus in terms of information the easier it is to recall and segregate from the background. For this reason representational models can confuse an otherwise simple signal by focusing on the structural properties between elements and not the properties of the constituent elements themselves. Different types of stimulus, in terms of the degree of complexity, will therefore elicit different combinations of structural properties and element properties resulting in the redundancy of different aspects of the signal. Top-down influences, i.e. previous knowledge regarding a stimulus, can also have an effect on what aspects of the signal are perceived as being redundant and subsequently what the simplest rule will be to interpret a pattern.

So if faced with a sequence of letters, *AAB*, and asked to extrapolate it, how would participants respond? Possible solutions include continuing the sequence via repetition *AABAAB* or by reflection *AABBAA*. However, when faced with the 3 letters AAB and asked to extrapolate the sequence, the majority of participants continue the series to *AABBCCDD* (Scharroo & Leeuwenberg, 2000). The results suggest that participants attempt to reduce their cognitive load by using the simplest method possible, in this example by trying to predict the rest of a sequence by continuing with the alphabet. Although the resulting sequence was not a direct symmetry of the first set of letters there was a bias towards a single repetition of each letter of the alphabet. In this sense the pattern involved a simple rule, repeat each letter of the alphabet once. However, this shows that information redundancy can also be achieved by prior knowledge of the stimulus type (van der Helm, 2000; Scharroo & Leeuwenberg, 2000). This is an important factor when considering how different visual stimuli encountered within daily life are perceived and processed. In the following section the salience of symmetry in the natural world and the processing of symmetry types are examined in further detail.

1.4 Processing theories of symmetry detection in humans

Various studies have highlighted the sensitivity of the human visual system towards symmetry and a preference for reflection over repetition (Barlow & Reeves, 1979; Baylis & Driver 1995,1993; Corbalis & Roldan, 1974; Wagemans, 1997, 1995). The detection of symmetry has also been noted as being important in the discrimination of figures and objects from the background (Baylis & Baylis, 1997; Baylis & Driver, 1995; de Kuija, Deregowski & McGeorge, 2004; Delius & Nowak, 1982; Rock, 1983). The following section discusses the detection of reflection and repetition amongst humans from the perspective of "processing theories".

It has been suggested that reflective symmetry requires less processing time than repetition or rotation (Julesz, 1971; Tyler, 1995; Wenderoth, 1994). Baylis and Driver (1995, 1994) examined the effect of reflective symmetry and repetition on object perception. Participants had to compare the contours of two images and identify if the contours were the same or different. Participants found the task easier when the two contours were a reflection of each other rather than presented in repetition. When the number of elements in each pattern half, i.e. the number of points in the contours, were increased from 4 to 16 there was no significant difference in the reaction times for the reflected condition. However, reaction times were slower in relation to increases in the number of elements for repetition (Baylis & Driver, 1994). Baylis and Driver (1995) therefore concluded that reflective symmetry detection is the result of parallel processing, i.e. the two contours are processed at the same time, and that the analysis of repetition was a serial process, i.e. the contours are processed sequentially one after another. Therefore it can be suggested that the translational symmetries, i.e. repetition, rotation and glide reflection, are processed serially as a consequence of having to attend to a new location, while the reflective symmetries create a more local object or grouping effect (Dill & Fahle, 1998, 1999; Wagemans, 1995). This supports the arguments, proposed by the representational models, that reflective symmetry is a particularly salient stimulus.

The perception of reflective symmetry has been shown to occur in times well within the 120ms limit (Barlow & Reeves, 1979; Baylis & Driver, 1994; Locher & Wagemans, 1993). If an object or figure can be perceived in under 160 ms then the stimulus can be considered as being perceived preattentively as there has been no time for saccadic or reflexive eye movements in order to shift or focus attention (Julesz, 1981). Hence reflective symmetry may be considered as being processed preattentively. However, this rapid processing of reflective symmetry only occurs if the patterns are presented in isolation. If the patterns are presented within the context of a group of stimuli then selective attention and a serial search is required (Olivers & van der Helm, 1998). This does not preclude the idea that some form of grouping, perhaps symmetry related, is occurring in parallel at early stages of processing, but does suggest that the results are context dependent.

However it has been demonstrated that display size can prove to be a significant factor in the perceptual advantage for reflective symmetry over repetition (Csatho, van der Vloed, & van der Helm, 2003). Csatho et al. (2003) confirmed earlier results that the human visual system is more sensitive to reflection than to repetition, however if the size of an image is increased then this preference was significantly reduced. This result could reflect that at greater magnifications the constituent parts of a mirror symmetrical pattern are more difficult to see as a Gestalt but rather are observed as individual units in their own right. This could result in the serial processing of the reflective pattern reducing any preferences in detection compared with repetition. This suggests that redundancy in information is a result of the grouping of elements, and the advantage exhibited by reflective symmetry in processing time is due to a Gestalt type grouping effect.

When bisymmetrical shapes are presented against asymmetrical backgrounds they tend to be perceived as figures in the foreground (Driver, Baylis & Rafal, 1992; Koffka, 1935). This suggests a possible preference for symmetry when locating objects within the visual field. As such, a pattern with a bisymmetrical arrangement might prove to be more readily perceived than one containing a repeated sequence. However, the axis of reflective symmetry could prove to be a significant factor in any perceived preference over repetition. The following section examines the role of orientation in reflective symmetry detection.

1.4.1 Orientation and proximity to the central axis

It has been suggested that the axis of reflective symmetry enables the accurate representation of the topology of biological shape and that this is therefore useful in pattern recognition and template matching (Koffka, 1935; Oka, van Tonder & Ejima, 2001). This could provide a partial explanation as to why different methods of mental computation are utilised in order to accurately perceive reflective symmetry as opposed to repetition within an object or pattern (Baylis & Driver, 1994). Reflective symmetry has been demonstrated to be more cognitively salient across the vertical and horizontal axis than across an oblique diagonal axis (Bornstein, Ferdinandsen & Gross, 1981; Palmer & Hemenway, 1978; Li & Westheimer, 1996; Vauclair, 1983; Wenderoth, 1994). Further evidence suggests that the processing for visual patterns reflected across the vertical axis occurs more efficiently compared to those reflected across the horizontal axis (Bornstein et al., 1981). The accuracy of reflective symmetry detection across the vertical axis is affected further by the proximity of the target area or figure to the central axis or point of fixation (Bruce & Morgan, 1975;; Dakin & Hess, 1997; Gurnsey, Herbert & Kenemy, 1998). This is the area of integration outside of which changes to symmetry cannot be detected (Dakin & Herbert, 1998). Therefore, the central axis of reflection might play a crucial role in the detection of symmetry and the grouping of symmetrical elements.

This preference for reflection across the vertical axis could be the consequence of the positioning of the sensory organs and the binocularity of foveal vision (Julesz, 1971). However as humans are bipedal, the bodily orientation in relation to gravitational cues could also bias perceptions of the environment. One study that investigated this issue considered the implications of micro-gravity (i.e. conditions where gravitational effects are greatly reduced) on the perception of reflective symmetry across one central axis (Leone, de Schonen & Lipshits, 1998). The participants, three cosmonauts, were required to identify whether a stimulus was symmetrical or non-symmetrical and the reaction times for each condition were recorded. Two types of stimulus were used, closed forms that consisted of closed polygons with 16 or 18 sides and open forms that were comprised of dot patterns.

In low gravity there was an increase in reaction times, i.e. a deficit in symmetry detection, towards identification of vertically symmetrical closed forms when viewed at fixation. This could suggest that there is a bias in reflective symmetry perception towards forms that are aligned with gravity. Therefore reflective symmetry detection of objects could involve an early visual process that utilises gravitational information. However, there was a decrease in reaction times for the detection of open forms with quicker reaction times in micro-gravity than in normal gravity. This suggests that reflective symmetry perception could be a multistage process and that detection of the open stimuli is assessed at later stages of visual perception and not gravity dependent. The small sample size means that the conclusions are not statistically significant, however they do suggest a novel explanation for observed perceptual biases towards reflective symmetry detection across the vertical axis.

The effects of micro-gravity on symmetry perception showed that there were no differences between symmetry perception in the peripheral field and the foveal field (Leone, De Schonen & Lipshits, 1998). This could imply that the saliency of reflected symmetrical patterns, where the symmetrical point pairs are close to the central axis, might not be due to the proximity of a stimulus to the foveal area but as a result of the size of the area of integration (Dakin & Herbert, 1998). However, these results in favour of vertically bisymmetrical stimuli can also be improved by the strength of other perceptual information contained within the stimulus, for example the contrast or brightness. Images that contain high contrast and brightness will preferentially capture attention over images that contain lower contrast and brightness (Franconeri, Hollingworth & Simons, 2005; Posner, 1980). The symmetrical nature of a stimulus is therefore not necessarily the primary characteristic that is detected during visual perception.

Additional processing involving extra-retinotopic visual working memory that has been described as a "visuo-spatial sketchpad" (Baddeley, 1997), can play an important role in the outcome of symmetry detection experiments that rely on reaction time. It could be at this late stage of processing that the filtering of pattern information occurs. Victor, Chubb and Conte (2004) performed a series of experiments examining which factors were most salient in a reflective symmetry based visual working memory task. One of the factors they examined in conjunction with reflective symmetry was luminance. The level of luminance was adjusted by varying the numbers of black checks in a checkerboard stimulus. Victor & Conte (2004) showed that when the luminance was altered, by increasing the number of black squares from 8 to 16 checks in an array, then there was a significant increase in the fraction of correct responses for the visual working memory task. This was an increase from 69% to 89% accuracy. For the change from 48 to 64 checks, the mostly black condition, there was a significant increase in accuracy, this time from 56% to 84% accuracy. In the symmetry part of the experiment they found that there was no significant difference between the two conditions, those with reflective symmetry across either the vertical or the horizontal axis. Therefore the effects of luminance on increasing stimulus saliency, perhaps over reflective symmetry pop-out effects, are a factor that needs to be accounted for in checkerboard style symmetry detection experiments. The dominance of luminance in a visual working memory task could suggest that the perception of reflective symmetry be a process that is occurring in extra retinotopic visual areas.

When interpreting the results of experiments investigating a preference for symmetry the type of stimuli and the method of presentation are significant factors that have to be considered. Only when these factors are controlled can the properties of a particular pattern type be examined. However, controlling these factors can reduce the external and ecological validity of the results, as they do not always reflect the context within which such conditions are experienced. A frequently encountered visual stimulus that exhibits reflective symmetry across a vertical central axis is that of the human face. The following sections review literature on ecologically valid stimuli, face detection and how faces provide a suitable candidate for a natural pattern.

1.5 Zoological evidence for biases in the processing of symmetry

Various types of symmetry are present throughout the environment, in natural objects and in the structural organisation of living organisms. It is therefore logical to expect that the visual systems of many organisms to be finely attuned to this particular characteristic of the visual world. It has been shown that preferences for bilateral mirror symmetry are common across many different animal species (Enquist & Johnstone, 1997; Möller & Thornhill, 1998; Swaddle, 1999). Bilateral symmetry in the male barn swallow, *Hirundo rustica*, has been shown to provide a signal to female birds regarding the mate quality and parasite resistance of a potential partner (Möller, 1990, 1992, 1993). Similarly, fluctuating symmetry, the deviations from perfect bilateral symmetry, have been shown to be an important indicator of mate quality and health in a range of animals including humans (Möller, Soler & Thornhill, 1995; Singh, 1995; Swaddle & Cuthill, 1995), damsel flies, *Coenagrion puella*, (Harvey & Walsh, 1993) and swordtail fish, *Xiphophorous cortezi* (Morris & Casey, 1998). Pigeons, *Columba livia*, have been show to be able to conceptualise the general concept of symmetry in object perception tasks (Delius & Nowak, 1982). Therefore a broad range of organisms each with varying cortical abilities utilise symmetry within their perceptual processes.

An example of the symbiotic nature of the evolution of symmetry perception and representation between two species can be illustrated by looking at pollinating insects and flower design. Flowers have evolved to exploit the symmetry perception mechanisms of pollinating insects, offering ultra-violet symmetrical signals on the flower surface and food rewards. For many pollinating insects, mirror symmetry represents a useful distinguishing characteristic of flowering plants and therefore is a criterion that can be utilised in foraging (Horridge, 1996, Möller, 1995). In one such experiment bumblebees, *Bombus terrestris*, were trained using sugar solution as a reward to fly towards either a bilaterally symmetrical stimulus or an asymmetric stimulus (Giurfa & Menzel, 1997). After achieving success in learning the two categories and responding to the appropriate conditioned images the bees were presented with novel asymmetric or bilateral symmetric stimuli, i.e. a stimulus that had not already been used in the conditioning trials. It was found that the bees that were trained to perceive bisymmetrical stimuli were more likely to transfer their training and continue flying towards the novel bisymmetrical stimuli while those conditioned to respond to the asymmetric stimuli were less likely to transfer the training. This illustrates that perception based on reflective symmetry requires only basic neural architecture and that for many animals the perception of symmetry is a valuable survival tool (Giurfa & Menzel, 1997; Giurfa et al. 1999; Giurfa et al., 2003). This suggests a basic mechanism for symmetry detection that does not require large amounts of cortical processing power, and is a basic function of many animal visual systems (Dakin & Herbert, 1998).

The zoological evidence provided so far has focused on reflective symmetry since evidence for a preference for repetition has not been readily investigated. However, the number of eyespots and therefore the number of repetitions on the tails of the male peacocks, *Pavo cristatus*, has been shown to be a mate quality preferred by peahens (Petrie, Halliday & Sanders, 1991). In turn the number of eyespots has been shown to correlate with the production of healthier offspring suggesting the repeated eyes spots are a signal of health and good genes (Petrie, 1994). In zebra finches, *Taeniopygia guttata*, female finches have been shown to exhibit a preference for male finches with bisymmetrical chest bar plumage (Swaddle & Cuthill, 1994). However, the chest bar plumage also exhibits repetitive symmetry. This could suggest that although the females are probably assessing the mates on the basis of fluctuating symmetry, a quality that is affected by developmental and past health, the repetition of the stimuli could amplify the signal. This would make reflective symmetry detection easier to detect due to the additional redundant information provided by the repetitions.

The significance of basic symmetry detection in insects is clear, however the complex neural architecture of vertebrates and in particular the human brain makes any direct link between symmetry perception and early visual processes more difficult. Within the insect visual system the detection of reflective symmetry is directly associated with the reward of food and no further level of computation or conceptualisation is required. However in humans the issues of attention, categorisation, and reinterpretation provide further complications in examining at what stage stimuli defined by symmetry-based criteria are processed within the brain.

1.6 The aesthetic properties of symmetry in facial stimuli

The zoological evidence presented in section 1.5 suggests that there are preferences for bilateral symmetry in the evaluation of potential mates. Although it is not possible to conclusively prove that mate choice in barn swallows or zebra finches is the result of an aesthetic preference or an appreciation for the qualities of symmetry, amongst humans it is possible to ask participants about their thoughts and reasoning. It has been shown that adults tend to show a preference for faces that are more symmetrical, exhibiting greater developmental stability and good health (Jones et al., 2004; Jones, Little & Perrett, 2003; Jones et al., 2001; Little et al., 2001; Opitz & Utkus, 2001). In experiments where male participants had to rate the attractiveness of female faces, the results show that the most symmetrical female faces are the ones that are rated as being most attractive (Baudouin & Tiberghein, 2004). This quality has been suggested as being a cross-cultural trait and perhaps an innate preference (Jones & Hill, 1993). Evidence from developmental studies suggests that infants exhibit a preference for faces that are perceived as being more attractive by adults (Langlois, Roggman & Reiser-Danner, 1990; Slater et al., 2000; Slater et al., 1998). This would therefore mean that the infants would also prefer those faces that exhibit greater reflective symmetry.

However most faces are not perfectly symmetrical. Fluctuating symmetry, the small deviations from bilateral symmetry, are suggested to represent responses to environmental challenges and developmental stress. In forced choice experiments where participants, both male and female, had to rate female bodies (without heads) there was a significant bias in preference towards the more symmetrical figures (Tovee, Tasker & Benson, 2000). The link between symmetry and health was examined further by Rhodes et al.

(2001) who noted that more symmetrical faces were rated as being healthier and suggested that amongst 17 year olds deviation from facial symmetry in boys was the result of developmental stress during childhood and poor current health in females. This would suggest that symmetry is perceived as attractive as it represents a predictor of good health (Mealey, Bridgstock & Townsend, 1999). However, Rhodes, Sumich & Byatt (1999) concluded that symmetry is secondary to averageness in predicting attractiveness. Despite this conclusion it can be argued that a face, which is the composite of several faces, i.e. averaged out, would have greater symmetry than any one of the individual constituent faces.

Nonetheless, there is further evidence suggesting that small deviations from perfect symmetry are what actually make a face attractive, and in many studies testing for a symmetrical preference it has been the perfectly bisymmetrical faces that come out as rated less attractive (Langlois, Roggman & Mussleman, 1994; Samuels et al., 1994). The faces that contain perfect symmetry in many respects will appear unnatural and inexpressive. However if participants are given the chance to manipulate the symmetry of a face themselves, then there is a preference towards more bisymmetrical faces (Perrett et al., 1999). Therefore although the individual deviations from perfect symmetry that provide cues to the expressiveness of the individual are important factors in face perception there is still a significant role for reflective symmetry as an aesthetic quality.

1.7 The perception of facial configuration

The human face is probably the most frequently encountered natural bisymmetrical pattern. All features within the face exhibit approximate reflective symmetry across a central vertical axis (Barton, Zhao & Keenan, 2003). The arrangement of these features results in a distinctive configuration as represented by the triangle in Figure 1.5. The individual features within the face also exhibit distinctive symmetrical and grouping properties. The eyes for example are a particularly salient high contrast feature that is not only reflected across the vertical axis but also contains repeated elements. For example Wilson et al. (2000) noted that gaze direction could be identified by deviations from the normal bisymmetry across the vertical axis. The following section explores evidence regarding the importance of configuration, featural elements and the salience of the eyes in regard to pattern perception and information redundancy.

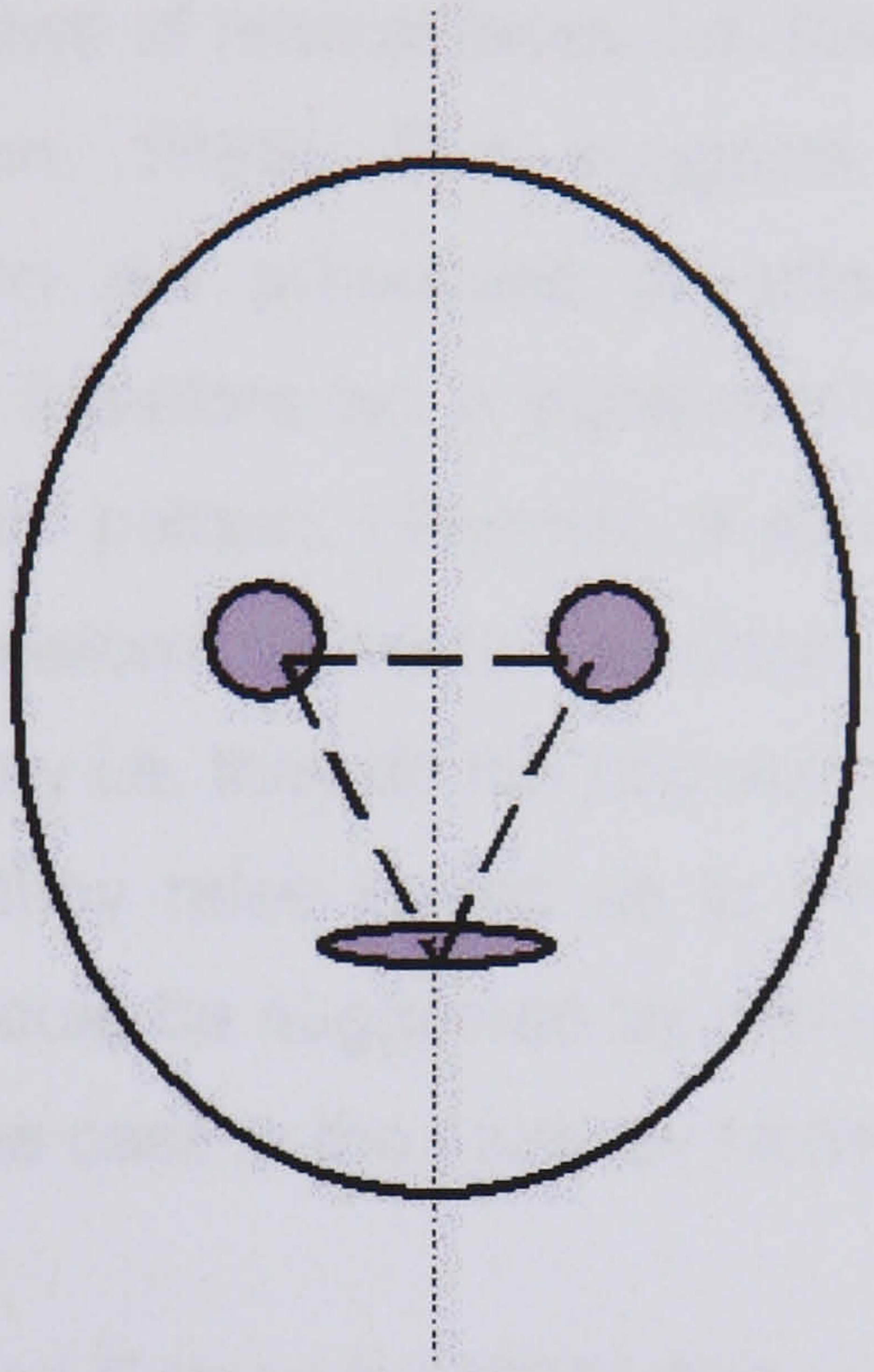


Figure 1.5: Schematic face showing the arrangement of eyes and mouth across the central vertical axis. The triangle represents the configuration of the elements together (Barton et al., 2003)

From birth there is an innate preference for looking at human faces (Dannemiller & Stephens, 1988; Maurer & Young, 1983; Mondloch et al., 1999) and as adults, humans are expert at face recognition and detection. The ability to recognise individual faces and expressions is essential for interpreting many of the daily social signals that are encountered within human society. Hershler & Hochstein (2005) showed that faces are particularly salient when presented within a search task amongst non-face objects exhibiting a strong "pop-out" effect. This they suggest is the result of high level processing areas. The average search time was around 1 second for detecting faces which is approximately twice as long as for traditional feature search experiments containing slanted lines or letters (Duncan & Humphreys, 1989; Treisman, 1991). This implies that although the detection of faces was rapid, it was probably not a process of early vision and required extensive top-down processing from face receptive areas of the extrastriate cortex.

The strong pop out effect suggests that faces possess characteristics and information that are very important to social signalling. It has been shown that faces exhibiting strong emotional content, in this example anger, appear to be identified rapidly from a crowd of neutral faces, i.e. the faces pop-out from the crowd (Hansen & Hansen, 1988). This suggests that faces containing potential threat information are processed pre-attentively. The emotional context of the stimuli can therefore be a significant factor in examining the ease of detection of a facial pattern. However, a similar experiment showed that faces and facial expressions presented amongst other distracting stimuli are not detected immediately i.e. they do not pop out (Nothdurft, 1993). These studies are important as they raise issues as to whether facial stimuli are processed in parallel as would be suggested by Hansen & Hansen (1988) or serially as appears to be the case in the study by Nothdurft (1993).

A further study by Lewis and Edmonds (2005) that examined the detection of faces within scrambled natural scenes suggests that faces do pop-out and are preferentially processed. However, if the faces were presented amongst inverted faces, then the participants adopted a serial search strategy. This study highlights that the processing of information is dependent on the context within which it is presented. Multiple faces and inverted faces can therefore have a detrimental effect on face detection, while presenting stimuli within a natural scene or emotional context can improve detection. In studies that require spotting faces from an array of other faces detection could be hindered by the repetitive nature of the arrays. The information present in the target face can become lost in the redundant information provided by the repetition of similarly configured distracter faces. However the evidence provided by Hershler & Hochstein (2005) and Lewis & Edmonds (2005) suggest that the human face possesses qualities that make it a particularly salient target in search tasks.

There is controversy over which qualities of the human face are responsible for the recognition and the rapid detection of facial stimuli. Various theories for face recognition have been put forward including the featural, configurational, holistic and norm hypotheses. The featural hypothesis suggests that faces are primarily remembered due to their facial features (Garner, 1978). The configurational hypothesis places the emphasis on the relationship amongst the facial features (Bartlett & Searcy, 1993; Diamond & Carey, 1986). The holistic hypothesis takes the face as a perceptual whole where both configurational and featural information are required for accurate recognition (Tanaka & Sengco, 1997). However the holistic hypothesis does place the configurational aspect as more important than the featural but does emphasise loss of either type of information as being detrimental to efficient face perception (Carbon & Leder, 2005; Farah, Wilson, Drain & Tanaka, 1998; Sergent, 1984). The norm hypothesis suggests a prototypical modular system for face processing whereby facial recognition is the result of deviations from a prototype norm-face (Light, Kayra-Stuart & Hollander, 1979). Faces that deviate markedly from the prototype are more readily recognised than those that are close to it.

Considering the face in a more holistic perspective, the configuration of the features becomes an important factor in the identification of the individual featural units (Tanaka & Sengco, 1997). In the experiments of Tanaka and Sengco (1997) participants were familiarised with different featural units within a face and then asked to identify the isolated features when presented either in the original face configuration, a new face configuration or in isolation. In the new configuration the space between the eyes was altered. The results suggested that the features are identified best when presented within the original face configuration, secondly in the new face configuration, and least in isolation. There were no configuration effects identified when the faces were presented upside down or when a non-face stimulus was used in this example a line drawing of a house. One significant aspect of this study was the effect that the movement of the eyes have on the configuration and identification of other facial units. Moving the space between the eyes had the effect of reducing accuracy in identifying the mouth and nose. By altering the distance between the eyes the perceived shape of the nose could be seen as being a different shape resulting in an observed reduction in accuracy in the identification of the nose (Rakover, 2002).

An alternative view (Rakover, 2002) is that of a hierarchical system where there is no bias towards either configurational or featural aspects but rather that the face is a multidimensional stimulus that is processed according to existing schemas in the cognitive system. Therefore there is a schema for the whole face, schemas for the individual features and a schema for the composite parts of individual features. The benefits of this hypothesis are that the existence of different schemas removes the need to split up the processing stages of the face in terms of configurational and featural and allows for the parallel processing of both at each of the hierarchical levels.

If the face is perceived as a Gestalt, a complete whole, and not as a result of underlying configural associations or featural elements then it could be argued that there is little difference in the recognition of objects and faces. It has been shown that expertise in face perception results in identification of faces at a subordinate, i.e. name, level as opposed to identification at the basic level, e.g. human (Tanaka, 2001). When face expertise was compared with that for common objects, the objects were spontaneously categorised at the basic level. However, this might vary for different objects, a chair is nearly always a chair and difficult to reduce to a subordinate level. Identifying faces at the name level suggests that the configurational properties of the face are taken for granted and that secondary cues that indicate the identity of the person are being picked up on. The preference for naming faces at the subordinate level suggests that there are over-riding top-down possesses that orientate attention towards the personal identity as opposed to the basic level. These top-down processes provide an additional form of redundancy that could allow for rapid facial pattern identification.

Individuals diagnosed with Asperger's syndrome and prosopagnosia provide an insight into the differences in object and face identification amongst individuals with attentional difficulties (De Haan, 1999; Trepagnier, Sebrechts & Peterson, 2002). Virtual reality (VR) headsets were used in order to eliminate conflicting external stimuli, so that the stimuli could be attended as fully as possible. The preliminary results showed that the Asperger's individuals had difficulties in identifying faces but were as good if not better at identifying objects when compared with control subjects. The results suggested that there could be a problem in looking at faces as configural wholes. However the experiment had to be stopped, as the Asperger's participants were uncomfortable wearing the VR headgear. This evidence suggests that face and object perception are processed in distinctly different ways. The configuration and relationship of the features across the vertical axis of symmetry are therefore factors that can be implicated in this processing distinction. The following sections examine further evidence regarding the importance of configuration and featural aspects can be obtained from examining the disruption to facial configuration caused by inversion and also from patients suffering from lesions to the brain resulting in prosopagnosia.

1.8 Face inversion

Inverting a face has been shown to disrupt the configural aspects of a face and reduce the accuracy of face recognition (Carey & Diamond, 1977; Leder & Bruce, 2000). In a classic example Thompson (1980) inverted the mouth and the eyes in an upright face of Margaret Thatcher to produce a grotesque version of the original image. However, when the face is inverted the image appears more neutral and the changes are more difficult to detect (Murray, Yong & Rhodes, 2000). This illusion has since become known as the Thatcher illusion. By changing the face in a way similar to the Thatcher illusion (Figure 1.6) there is a disruption of the configural information but not of the featural information (Bertin & Bhatt, 2004; Boutsen & Humphreys, 2003; Leder & Bruce, 2000; Tanaka & Farah, 1991). This could suggest that to an extent the holistic hypothesis of face detection is correct, as the face would be perceived as a complete gestalt (Tanaka & Farah, 1993).

Figure 1.6: Example of a 'Thatcher' illusion

In a qualitative analysis of the Thatcher illusion Murray, Yong & Rhodes (2000) showed that using a 7-point scale, where 7 is very bizarre and 1 is not bizarre at all, participants rate the Thatcherized face as more bizarre the closer the images are to the upright position. However, they also showed that if the components were altered or distorted, then the images were consistently rated as being bizarre regardless of the orientation. Unaltered faces were always perceived as being normal. The evidence suggests again a disruption of configuration and spatial relationships but not of the components in the inverted Thatcher illusion. Evidence for this effect, using the Thatcher illusion, has been identified in 6-month old infants suggesting that the ability to discriminate faces based on configuration could be an innate property (Bertin & Bhatt, 2004).

By inverting the eyes and mouth within a Thatcher illusion within the upright image results in a disruption of the configural and component aspects of the image resulting in a distorted face. When the face is rotated the features are in the correct orientation so this aspect of face processing appears to be normalise the face. Schwaniger, Carbon & Leder (2003) suggested that rotated faces overtax an orientation normalisation mechanism so that they have to be processed by their components resulting in the neutral face for the Thatcher illusion. These examples highlight the importance of both the configural processing in upright faces and of the components in the inverted faces. If the components are examined in terms of their position along the vertical axis, it is noticeable that although during inversion the positions change, the bisymmetrical nature of the face does not. The symmetries of the face, both repetition and mirror, are still preserved and this might add to the illusion of neutrality in an inverted Thatcherized face.

As in the studies of symmetry orientation in mircro-gravity (Leone, de Schonen & Lipshits, 1998), the inversion effect could be sensitive to either graviceptive cues affecting the perception of lines of symmetry or due to the physical orientation of the body and visual system. In a comparison between faces learnt on the ground and faces learnt in low gravity conditions it was found that faces learnt in low gravity were still subject to the inversion effect with a reduction in the accuracy of recognition for inverted faces compared with normal faces (de Schonen, Leone & Lipshits, 1998). However, if the faces were learned in flight, where the loss of gravity is simulated, then there was an overall reduction in the ability to recognise faces. It is argued that gravity might be necessary for the first processing stages of faces, i.e. the detection of vertical lines of symmetry and configuration, however once remembered the inversion effect holds true. This suggests that the inversion effect is a later stage of processing that utilises already established pattern information about faces. Therefore long term encoding utilises retinal and body orientation as opposed to gravity orientation.

In the final example of face inversion, Campbell et al. (1997) examined identification of different species by morphing the faces of humans with cows, humans with monkeys, and cow with monkeys. The participants had to identify which species the morphed faces were closer to. For upright faces there was accurate categorisation into species boundaries. For upside down faces identification was slower and the boundary between human and monkey was not so distinct. This provides a novel slant on the face inversion experiments in that it suggests that subtle differences in the configuration of faces of closely related species, macaque and human, can become difficult to discern when inverted. However differences between primate and bovine features are very distinct and incorporate significant featural changes making the hybrid faces easier to classify. Therefore, the disruption of configuration, i.e. patterning, via inversion may confuse the normal processing of faces.

1.9 Developmental perspective on face perception

It has been suggested that infants are born with an already detailed representation of the human face, sensitive to facial orientation and emotional expression (Quinn & Slater, 2003; Meltzoff, 1995). Further evidence suggests that 3-month old infants are capable of remembering faces in long-term memory (Rovee-Collier, 1990; Pascalis & Bachevalier, 1998). However there are marked differences between the ways infants of different ages and adults perceive and process facial stimuli. In 4-day-old neonates there appears to be little configural processing of facial stimuli (Pascalis et al., 1995). Neonates will fixate on a mothers face longer than that of a stranger's suggesting that they are able to recognise the maternal face, however if there is no discrimination between mother and stranger if both the women are wearing headscarves. This suggests that the neonate is utilising the outer contours of the mothers face and not the internal features for recognition. This might be due to poor visual acuity during the early stages of life (Abramov et al., 1982; Bronson, 1974; Johnson, 1990) and does not necessarily mean that there is not an underlying innate face processing system. At 1 month old there is still a bias towards fixation on a limited portion of the perimeter, however by 2 months old there is a switch to fixating on the features of faces (Maurer & Salapatek, 1976).

Other studies of neonates suggest that at birth there is a preference for facial patterns (Johnson, Posner & Rothbart, 1991; Valenza et al., 1996). Johnson & Morton (1991) suggest that this preference is because face-like patterns are special because of the structural organisation or configuration, of their internal features. However, the stimuli used were not pictures of real faces but abstract representations that represent the position of features using black squares. Therefore, the newborn preference for faces could be the result of a number of less specific attentional biases that cause the human face to be the frequent focus of an infant's attention (Simion et al., 2003). The configuration is obviously a salient feature and with improving acuity as shown with the 2-month old infants a key factor in face detection.

Another method of examining face processing is the use of electroencephalography. The N170 is a face sensitive event related potential that is most prominent over the occipto-temporal regions of the scalp. In adults the N170 has been shown to have a shorter latency and higher amplitude for upright faces when compared with other non-face stimuli (Bentin et al., 1996). However in 6-month old infants the specificity of the N170 for faces is not as strong as in the adults (de Haan, Pascalis & Johnson, 2002). de Haan et al. suggest that this indicates a gradual specialisation of cortical face processing areas during postnatal development. By 8 months old infants there is a bias towards utilising configural information to process photographs of faces, although featural information can be recognised too (Schwarzer & Zauner, 2003).

It appears that in infants and neonates facial processing is experience expectant in that there is a readiness of the brain to receive certain types of information that are common to the entire species at particular periods of time (Nelson, 2001). Therefore domain specific areas for the visual perception of particular pattern types or images can be refined into highly specialised processing areas as with face perception. This is in concordance with the idea that there is a predisposition towards expertise and specificity within the brain for face perception. However it does not mean that there has to be an innate face template present at birth, as per the norm face perception hypothesis, but it does mean that particular pattern types and configurations such as those used by Johnson & Morton (1991) can act as the basis for increased specialisation towards face processing.

In developmental studies there is a strong argument for investigating face perception and symmetry detection together. Studies on 4-month-old infants have shown that there are preferences in the infants for looking at stimuli that possess bilateral symmetry across a vertical axis of reflection (Bornstein, Ferdinandsen & Gross, 1981; Fisher, Ferdinandsen & Bornstein, 1981). The preference for mirror symmetry across the vertical axis has been suggested as being innate while the detection of other symmetry types could develop later (Bornstein, Ferdinandsen & Gross, 1981). This apparent innate sensitivity could be a result of the anatomical arrangements of the visual system (Julesz, 1971), a bias towards scanning across the horizontal plane (Salapatek, 1975) or experience in that faces play an important role in an infant's visual life. This vertical symmetry bias could prove vital in the development of face recognition, as infants appear to show a bias towards the global features of an image rather than the local features (Atkinson, 2000). Therefore an innate ability to recognise visual patterns would prove essential in the perception of faces or the development of face processing.

If there are innate modules within the human brain for face perception then these modules must be present in some reduced form in closely related species. Evidence for the evolution of expertise in human face processing within the temporal cortex can be found by examining examples of human face perception in other species. For example sheep are very good at memorising both sheep and human faces (Kendrick, 2004; Kendrick & Baldwin, 1987). Work by Kendrick et al. (2001) has shown that sheep possess cells in the temporal cortex that behave similarly to those in the humans in that they exhibit a preference for human faces. In more closely related species similar areas of the superior temporal cortex have been identified that are responsive to facial stimuli within macaques (Desimone, 1991; Perret et al., 1985). This might suggest that the human face processing areas are the result of repetition and refinement of structures sensitive to configural information that are already present within the basic mammalian brain. The following section considers the facial attributes that may be critical in this regard.

1.10 Eyes as an important social signal and visual pattern

The eyes are a distinctive facial feature and can be perceived as being grouped by the law of similarity and proximity. The shape of the eyes can be described in terms of the law of closure and the way eyes move can be described in terms of common fate. Eyes also exhibit properties that are approximately repeated and reflected. Therefore eyes possess all the criteria of a facial feature that has high figural goodness. Eyes are also essential in face recognition. Direct eye gaze has been shown to influence both the encoding and retrieval phases of face perception (Hood et al., 2003). The following section examines why the eyes are an important feature in face identification and social signalling.

The demands of group living place selection pressures on an organism to decipher and predict the behaviour of conspecifics, especially in situations of conflict and competition. Therefore, the ability to gain insight into the thoughts of others would prove to be hugely beneficial and help in maintain a stable social group (Byrne, 1995; Dunbar, 2004; Shettleworth, 1999). These behaviours can include social grooming, vocal signals and visual signals. Eye gaze is a particularly important visual signal among many primate species. Gaze detection provides a useful indicator of the intentions of other individuals (Mealey, 1997), and is utilised in many situations such as courtship (Emery, 2000; Wada, 1961), foraging (Tomasello, Call & Hare, 1998), and learning (Mineka, 1984).

However, while assessment of eye gaze may be the most reliable cue (Thomsen, 1974), the orientation of the head and body, which also display direction specific activity in selected cell populations (Hains & Muir, 1996; Perrett et al., 1985; Wilson et al., 2000), provide additional information as to the focus of another's attention. This hierarchy of cues, though, seems to vary from species to species, and this may be a function of the degree of sociality necessary for that species survival. The morphology of monkey faces may aid in the determination of attention without the use of eye gaze as a cue through the orientation of projecting snouts, protruding noses or facial flanges. Apes for the most part have far flatter faces, promoting the eyes, which are often framed and accentuated by higher cheekbones and brow ridges, to a more crucial position for determining direction of attention (Emery, 2000). It may be for this reason that the eyes of apes show far more contrast between the dark iris and the lighter sclera of the eye, to facilitate the establishment of the focus of attention.

The contrast between the iris and the sclera is particularly apparent in humans. While the sclera of humans is white the sclera of most other animals varies within differing shades of brown, this therefore makes the human eye a strong social signal (Kobayashi & Kohshima, 1997). In a study by Ricciardelli, Baylis and Driver (2000) the polarity of photographs of human eyes were reversed, making the sclera darker than the iris, they found that as long as the iris was sufficiently darker than the sclera, eye gaze could still be determined. As the contrast is decreased the efficiency of eye perception is also decreased (Perrett & Mistlin, 1991). Eye cues are used less frequently as the distance between the dyad increases, due in part to both the declining resolution of the details of the eye, but also the fewer social activities engaged in between the two individuals as distance increases (Martin & Jones, 1982). There is an adult aesthetic preference for larger eyes on a face while 5-month old infants show a modest preference, measured in looking time, for photographs with larger eyes (Geldart, 1999). In neonates there is already a preference for stimuli that contain high contrast and optimal spatial frequency, similar to that of the sclera and iris (Valenza et al., 1996). This evidence could suggest a basic visual process or preference for eye-like stimuli.

For 12-month-old infants and to a greater extent 14-month-old infants eye gaze has been identified as an important factor in directing attention (Caron, Butler & Brookes, 2002). In these studies an adult would sit in front of an infant and orientate their attention towards a target using one of three conditions. The 3 conditions used all involved the head being turned towards the target and either eye gaze directed towards target, eyes looking straight ahead, or eyes closed. The infants responded to a greater extent to the eye gaze directed towards the target condition and to a significantly less extent to the condition where the eyes were closed. This suggests that from a very early age eye gaze is an important factor in social communication and learning.

Facial configuration has been shown to play an important role in the information that is picked up from eye gaze (Farroni et al., 2003). Farroni et al. tested 4-month old infants and whether the eye gaze alone was the key factor in cueing attention. Their results showed that a period of mutual gaze prior to the eye gaze shift was important when cueing spatial locations. They also noted that when the face presented was inverted, eye gaze did not have a significant effect on the cueing of spatial locations. These results suggest that the location of the eyes within the configuration of the face is an important factor in the eye-gaze phenomenon.

Within human societies facial expressions are of particular importance as much human social grooming is in the form of conversation and gossip (Dunbar, 1996) and therefore orthogonally detected. Eye gaze, as a signal that can be detected face-on, can provide an indicator of interest, intention and turn taking within conversation groups and has been implicated in the detection of emotion (Adams & Kleck, 2005), opportunities for sexual encounters, potential aggression (Fox, 2005; Kampe et al., 2001) and communicating information (Doherty-Sneddon & Kent, 1996). The examples all highlight the value of gaze detection in understanding the beliefs and intentions of other individual. This type of knowledge is known as Theory of Mind, ToM (Baron-Cohen, Wheelright & Jolliffe,1997).

ToM is arguably the exclusive human ability to acknowledge the private mental world of another human and to take their perspective. It is clear that this ability would enable us to assess the intentions of another and avoid being cheated on in social transactions and avoid making enemies through miscommunication. Baron-Cohen (1997) posits an '*eye direction detector module*' as one of four modules of a mind reading system the others being the 'intentionality detector', the 'shared attention mechanism', and the 'Theory of Mind mechanism'. Any damage or malfunction of the mind reading system would result in severe social impairment. Baron-Cohen points to evidence showing that people with disorders along the autistic spectrum (who display a handicap in their ToM function) show a severe impairment in their ability to read the direction of gaze of another. This is supported by a large volume of related research on deficits in eye-gaze detection amongst autistic individuals (Baron-Cohen et al., 1999; Baron-Cohen et al., 1997; Leekam, Hunnisett & Moore, 1998; Ruffman et al., 2001; Tanaka, Lincoln & Hegg, 2003; Trepagnier et al., 2002; Yirmiya et al., 1999). The evidence so far suggests that the characteristic high contrast, approximately symmetrical and repeated nature of the eyes, has evolved as a signal that is designed to provide complex information. Redundancy in this information is provided by the arrangement of the eyes in an approximately reflected pair. This signal can modulate attention towards an intended target with minimal information content.

It is therefore suggested that perception of eye gaze can result in an automatic switch in attention towards the implied directional cue (Driver et al., 1999; Langton & Bruce, 1999; Langton, Watts & Bruce, 2000). However, Tipples (2002) suggests that this is not a unique property of eye gaze but that automatic orienting can occur in response to any directional cues, for example arrows. This argument was supported by the work of Pellicano and Rhodes (2003) who suggest that there is not a special role for eye gaze in the development of ToM. Pellicano & Rhodes observed that although children aged between 3 and 4 years old do use eye gaze as a directional cue to infer the mental states of others, the children would also use other directional cues, for example an arrow, to ascertain the same information, e.g. the location of a desired sweet. A plausible alternative explanation to the results obtained by Tipples (2002) and Pellicano and Rhodes (2003) could be that the arrow has a particularly strong cultural meaning to the children and that eye gaze represents a culturally independent and possibly even species independent method of communicating direction and intention. However, both the arrows and the eyes share common patterned properties, in particular the Gestalt rule of common fate/ direction. Hence the patterned properties of the stimuli might explain the similarities between the eye gaze direction and arrowhead stimuli.

Symmetry and figural goodness provide a means for reducing the information load on the visual system. These properties are all present within the human face, a commonly experienced bilaterally symmetrical stimulus.

Within the face features, the eyes provide an important pattern utilised in face identification and social signals. This thesis aims to examine what constitutes a visual pattern and when patterning is imposed or detected by the visual system. These issues will be examined in regard to both abstract patterns and patterns with higher ecological relevance, i.e. human faces and human social groupings.

1.11 Summary

Patterns can be defined as providing a way of reducing the information content in the optic array. Two important pattern types, repetition and reflection will be examined in this thesis. Reflective symmetry across the vertical axis appears to be a highly salient visual feature and processed in parallel while repetition appears to be processed serially. Symmetry detection is common throughout the animal kingdom and is particularly important in human visual perception. The human face provides an example of a stimulus that posses many symmetrical qualities. Various theories of face detection were discussed including importance of the arrangement of the features within the human face. This configural information appears to be crucial in face perception and detection. The eyes, a facial element that is high contrast, approximately repeated and approximately reflected represent a particularly salient pattern that is important in face perception.

Chapter 2: Visual processing of patterns

The following chapter provides a basic overview of the visual system and discusses the neuroanatomical evidence for selective processing of patterns and faces. The information present within visual patterns is initially broken down by the visual system into orientation, spatial frequency, contrast and chromatic components (Blakemore & Campbell, 1969; Zeki et al., 1991). From this information the visual system can analyse, identify and refine the perception of visual patterns into meaningful cognitive information, for example in the recognition of faces. This chapter charts the time course and neuroanatomical evidence for visual pattern perception and top-down vs. bottom-up perspectives of visual processing.

2.1 Retinal vision

Different wavelengths of light are differentially absorbed, transmitted and reflected by the objects encountered within the environment. These provide the necessary cues that are needed by the vertebrate eye and brain to ascertain the various properties, shape, texture, and colour of an object. The vertebrate brain therefore has to distinguish and sort out a myriad of patterns into objects, textures and backgrounds in order to provide the best possible mental conceptualisation of the habitat within which an organism lives. Vision is one of the most important of vertebrate senses. This can largely be attributed to the speed with which light travels (3 x 108m/sec within a vacuum), and as a result vision provides an almost instantaneous cue to the immediate environment of an organism. However only a limited range of wavelengths (400 - 700nm) within the electromagnetic radiation spectrum can actually be perceived by the human visual system (Bruce, Green & Georgeson, 1996; Gregory, 1998; Mollon, 1982).

The initial stages of vision take the form of a feedforward system. The rays of light that reach the eye diverge in multiple directions from their source. The cornea and lens of the eye refract and focus the light onto the retina. The retina is divided into 3 layers, the photoreceptor layer, the bipolar layer and the ganglion cell layer. There are 5 types of neurons in the retina, the ganglion cells, amacrine cells, bipolar cells, horizontal cells and photoreceptor cells (Figure 2.1). Within the outermost retinal layer there are two distinct types of photoreceptor cells, these are known as cone cells and rod cells. In humans there are between 100 and 120 million rod cells and between 3 and 6 million cone cells (Farah, 2000; Purves et al., 2001; Tovee, 1996). The photoreceptors form synapses with bipolar cells that in turn form synapses with the ganglion cells, the axons of ganglion cells travel through the optic nerves to the brain.

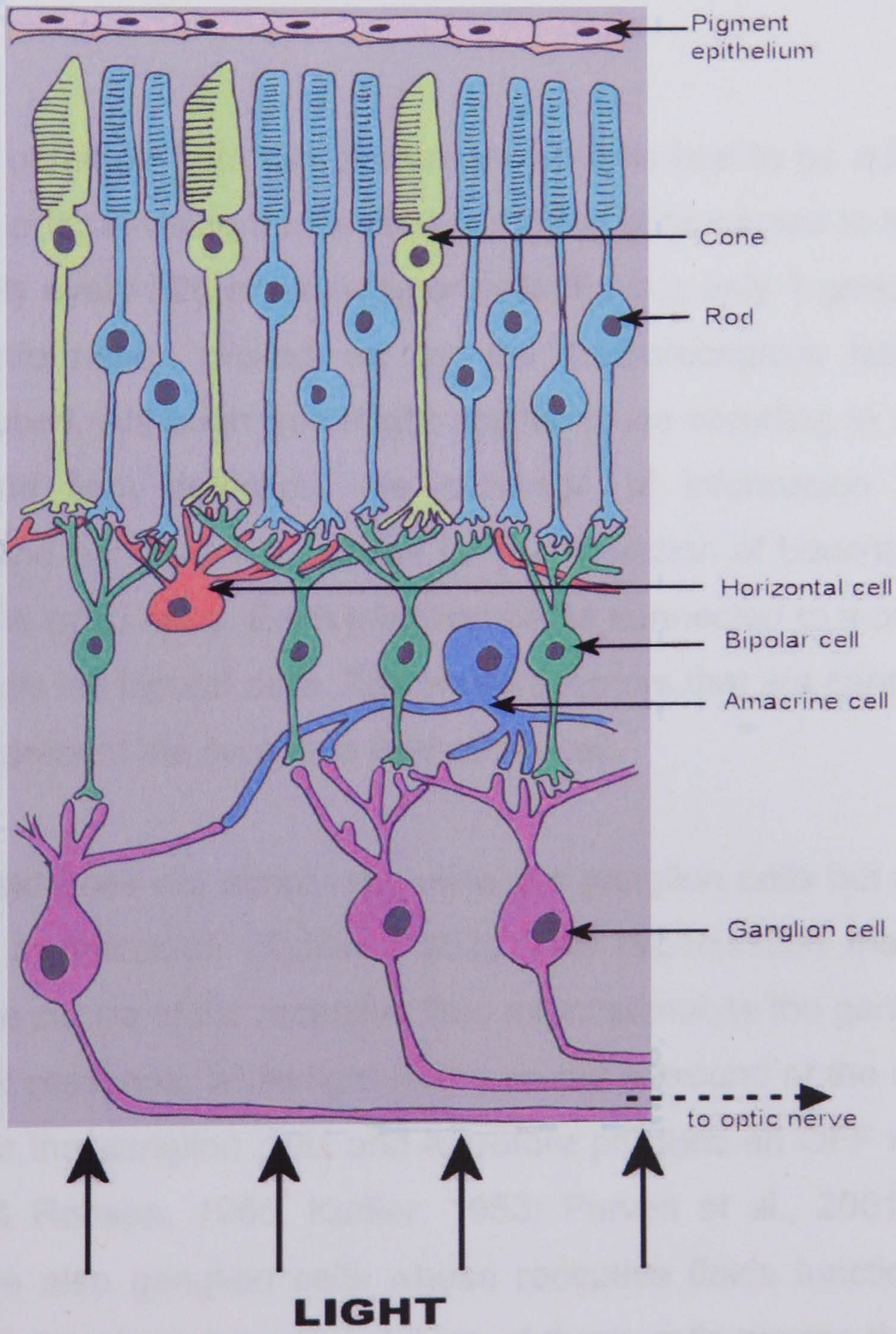


Figure 2.1: Schematic diagram of the human retina illustrating the different types of cell (adapted from Coren, Porac & Ward, 1979).

The photoreceptor cells carry out the transduction of light into neural activity. The rod cells provide low acuity, monochrome vision and are sensitive to low levels of light. The cone cells provide higher resolution colour vision providing there is sufficient light. Each cone cell contains one of three photopigments that are maximally sensitive to a specific wavelength of light; these are blue-violet (419nm), green (531nm), and yellow-red (558nm) light (Dartnall, Bowmaker & Mollon, 1983). There is an absence of rod cells within the fovea, however this is the area of the retina that contains the highest concentrations of cone cells (Sekuler & Blake, 1994: see Figure 2.2). Across the rest of the retina rod cells dominate; the fovea is therefore the region of highest acuity vision.

The information obtained from the photoreceptor cells has to be condensed and reorganised prior to being transmitted along the optic nerves to the brain. For approximately every 126 photoreceptor cells there is only 1 ganglion cell, therefore the information picked up by the photoreceptors has to be significantly reduced. Although this might appear to be resulting in a loss in visual acuity and light detection, the reduction of information between photoreceptors and ganglion cells allows for the detection of boundaries and patterns within the optic array. Each ganglion cell is connected to a number of photoreceptor cells via bipolar cells. The photoreceptors that are connected to ganglion cells represent the receptive field of the cell.

The receptive field does not simply stimulate the ganglion cells but acts in a centre-surround organisation (Kuffler, 1953). This organisation means that light falling on the centre of the receptive field might stimulate the ganglion cell producing an ON response, while light falling on the surround of the receptive field might inhibit the ganglion cells and therefore produce an OFF response (Enroth-Cugell & Robson, 1966; Kuffler, 1953; Purves et al., 2001; Tovee, 1996). There are also ganglion cells whose receptive fields function in the opposite manner. However the arrangement of these cells means that if light is falling evenly across the receptive field, the ganglion cell is both inhibited and stimulated therefore producing a null response, however if light falls in one particular area of the receptive field then the ganglion cells will either be stimulated or inhibited. The differences between the ON-centre responses and the OFF-centre responses provide an essential function in detecting contrast differences and edge detection within visual scenes. Such a response is essential in pattern detection as it provides a method of detecting boundaries and the spatial arrangement of elements within the receptive field.

The retina therefore behaves in a similar way to a mini parallel processor in that different photoreceptors provide different sensitivities to different wavelengths and this information is condensed via the ganglion cells into useful spatial information. To summarise the rods are more sensitive to light than the cones, however rather than sacrifice resolution the retina also possesses cones that have higher visual acuity and provide colour vision. So at the retinal stage all the chromatic, contrast, and spatial information that is required for pattern perception ready to be analysed further within the brain. Even at such an early stage of visual processing there is evidence of a segregation of labour that has been suggested to continue right through the system up to the striate cortex (Livingstone & Hubel, 1988).

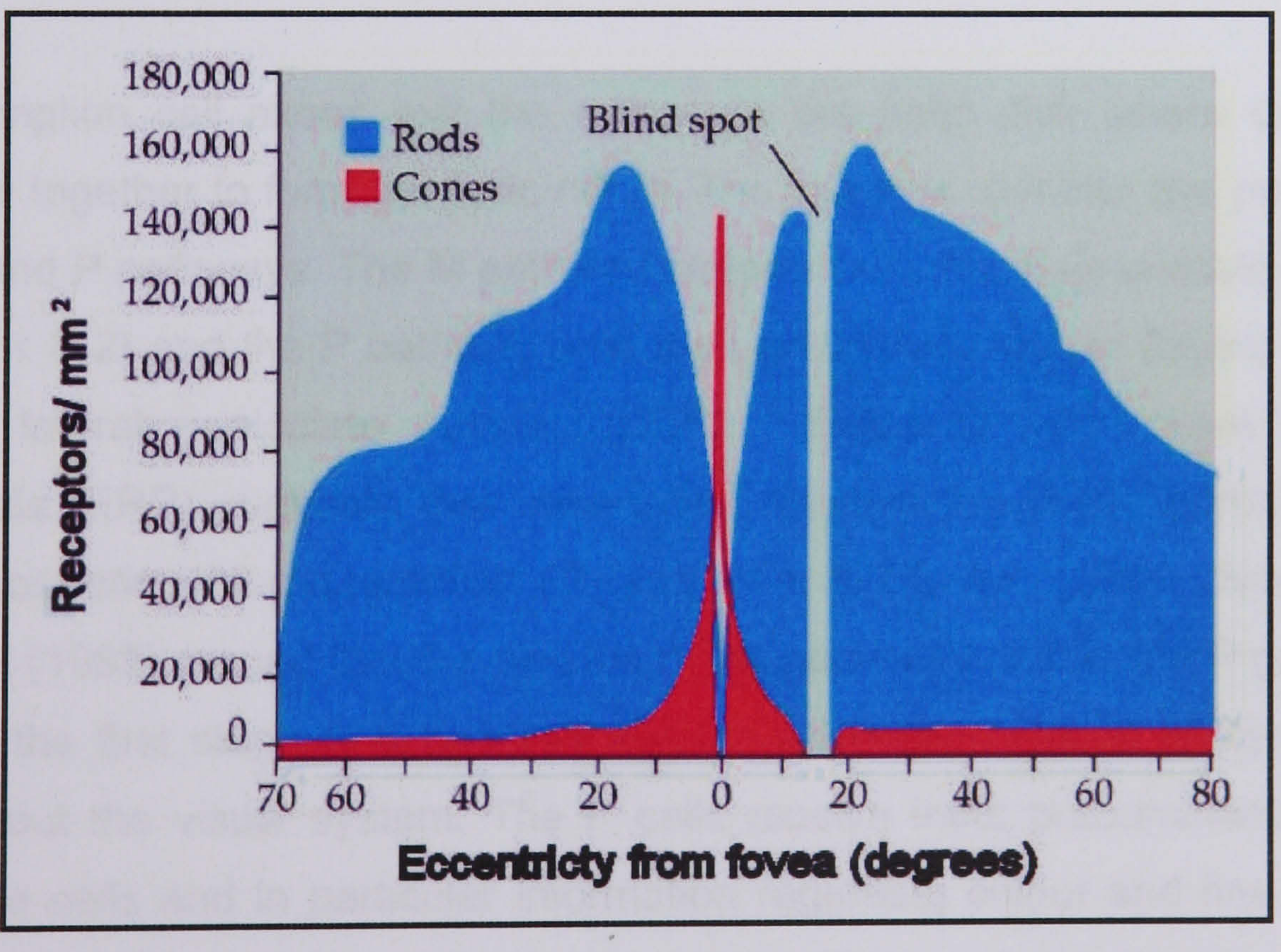


Figure 2.2: The frequency of rods and cones in the retina (adapted from Palmer, 1999)

However the detection of such signals will be constrained by the visual hardware used. Problems such as blind spots, the field of high acuity vision will all impede on visual perceptions of groupings and objects within the visual field. Within the nasal retinal field there is blind spot that occupies approximately 5° to 8° of the visual field created by the exit of optic nerve from the retina (Purves et al., 2000). This blind spot is located around 15° to 20° of the fovea. This could narrow the focus of attention when perceiving patterns or discerning individuals within social groups. The blind spot is not consciously noticed in everyday life as the temporal retinal field of the opposite eye fills in any gaps (Ramachandran & Gregory, 1991). Despite filling-in, information presented within in this area will not be subject to the same visual acuity as objects presented to the fovea; this means that fine detail might not be accurately represented. However, by taking advantage of patterns within the visual field any gaps in the representation of the visual field can be accounted for. The high concentration of photoreceptors proximate to the fovea and the blind spot provides a retinal pick-up limitation that could explain the bias in perception of elements reflected proximate to the central axis of reflection (Dakin & Herbert, 1998).

2.2 The Lateral Geniculate Nucleus (LGN) pathway

The ganglion cell axons exit the retina via the optic disk where they are bundled together to form the optic nerve. The image is split into two pathways the M and P pathways. The M pathway projects onto the magnocellular layers (layers 1 & 2) and the P pathway onto the parvocellular layers (layers 3 to 6) of the lateral geniculate nucleus (LGN). Evidence from event related potentials (ERP) suggests that information reaches the LGN approximately 30ms post stimulus presentation (Thorpe, Fize & Marlow, 1996). Livingstone & Hubel (1988) argued that the division of the pathways into M and P ganglion cells is the first stage of a two-way division of function that is continued on throughout the visual system. The P cells receive input predominantly from the cone cells and in particular information regarding colour and fine spatial structure, whereas the M cells process information regarding the large-scale spatial layouts and contrast predominantly from the rod cells. However, visual information is also projected forward to the superior colliculus that provides a sub-cortical visual pathway.

By purposefully inflicting lesions within the LGN of a macaque it has been possible for neurophysiologists to separate out the functions of each pathway. Schiller, Logothetis and Charles (1990) showed that when there were lesions to the P layers of the LGN the animal had difficulty in performing tasks that required the use of stimuli that were presented within the affected part of the visual field. These included difficulties in discriminating colour, texture, shape and pattern. However when the M layers were damaged the animals were still capable of discriminating large scale spatial patterns but there were deficits in their ability to detect differences between rapidly flickering stimuli and steady images and problems with the detection of movement within complex displays. This has lead to the suggestion that the M pathway is equipped for detecting motion and spatial awareness, while the P pathway is more concerned with object recognition (Figure 2.3).

However there is danger in trying to separate the functions of the M and P pathways into distinct separate processing streams. Although it has been shown that the M ganglion cells are more sensitive to contrast, it has also been shown that it is in fact lesions to the P and not the M layers that cause the greatest effect in detecting contrast (Schiller et al., 1990; Van Essen, Anderson & Felleman, 1992). As P cells outnumber M cells the increased number could mean that the P cell population is having a greater overall effect on sensitivity than the M cell population. So it is with caution that the conclusions can be made from evidence at a purely cellular level. This also emphasises the point that the human visual system does not rely solely on one type of photoreceptor or specialise in one particular type of visual task (e.g. night vision, motion detection). Instead evolution has equipped us with a multipurpose eye and the corresponding hardware to match.

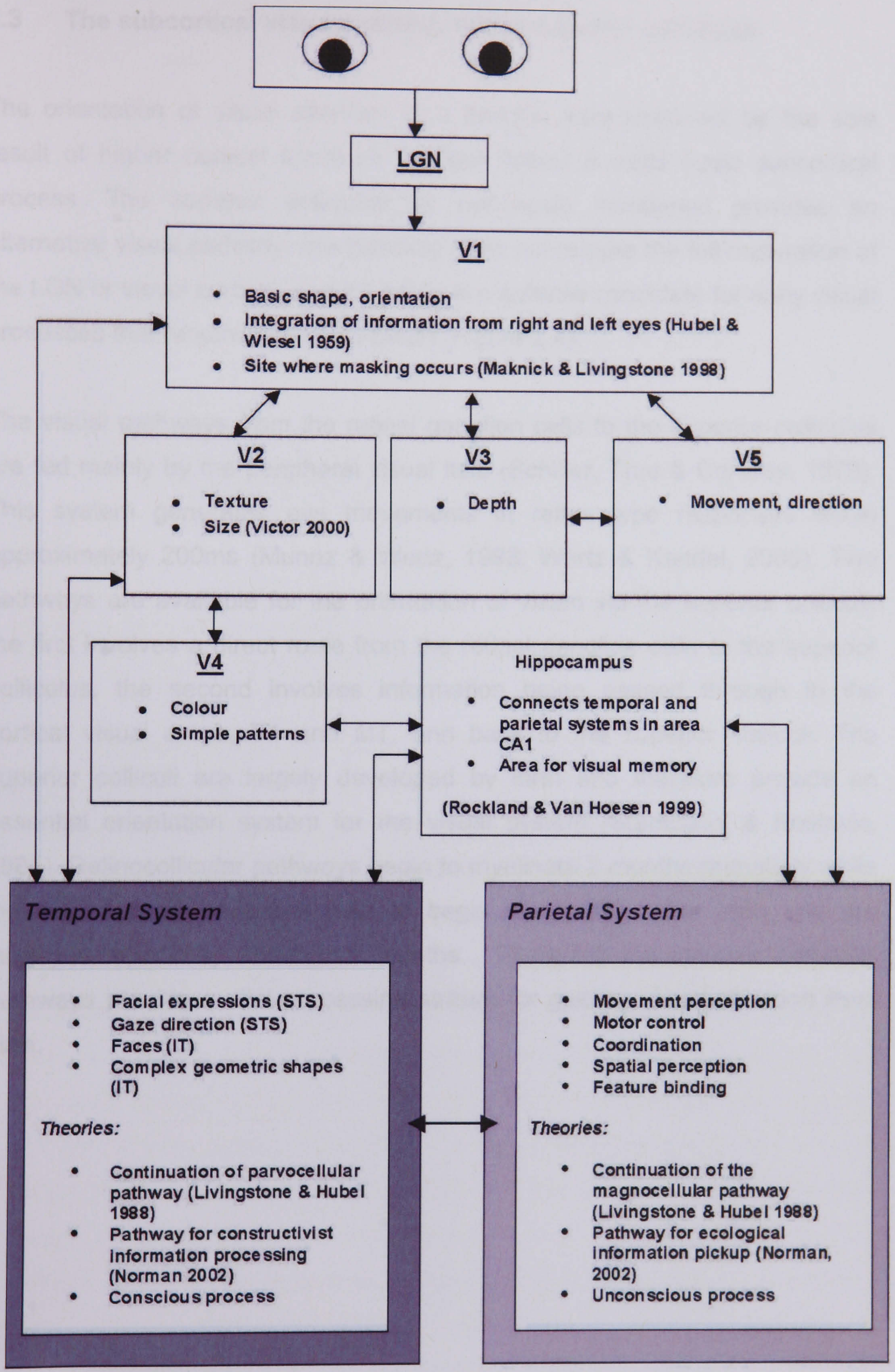


Figure 2.3: An overview of the visual system, from the LGN onwards, illustrating the division of processing into the temporal (ventral) system and parietal (dorsal) system.

2.3 The subcortical visual pathway of the superior colliculus

The orientation of visual attention to a specific area need not be the sole result of higher cortical functions but can reflect a more basic subcortical process. The superior colliculus as previously mentioned provides an alternative visual pathway; this pathway does not require the full maturation of the LGN or visual cortices and therefore is a suitable candidate for early visual processes that require rapid orientation (Figure 2.4).

The visual pathways from the retinal ganglion cells to the superior colliculus are fed mainly by the peripheral visual field (Schiller, True & Conway, 1979). This system generates eye movements in reflex type responses within approximately 200ms (Munoz & Wurtz, 1993; Wurtz & Kandel, 2000). Two pathways are available for the orientation of vision via the superior colliculi, the first involves a direct route from the retinal ganglion cells to the superior colliculus, the second involves information being passed through to the cortical visual areas, V1 and MT, and back to the superior colliculi. The superior colliculi are largely developed by birth and therefore provide an essential orientation system for the visual system (Stampalija & Kostovic, 1981). Retinocollicular pathways begin to myelinate 2 months prenatally while the retinocortical pathways tend to begin myelination after birth and are largely complete by about four months. Therefore the superior collicular pathways provide a vital processing stream for guiding visual attention from birth.

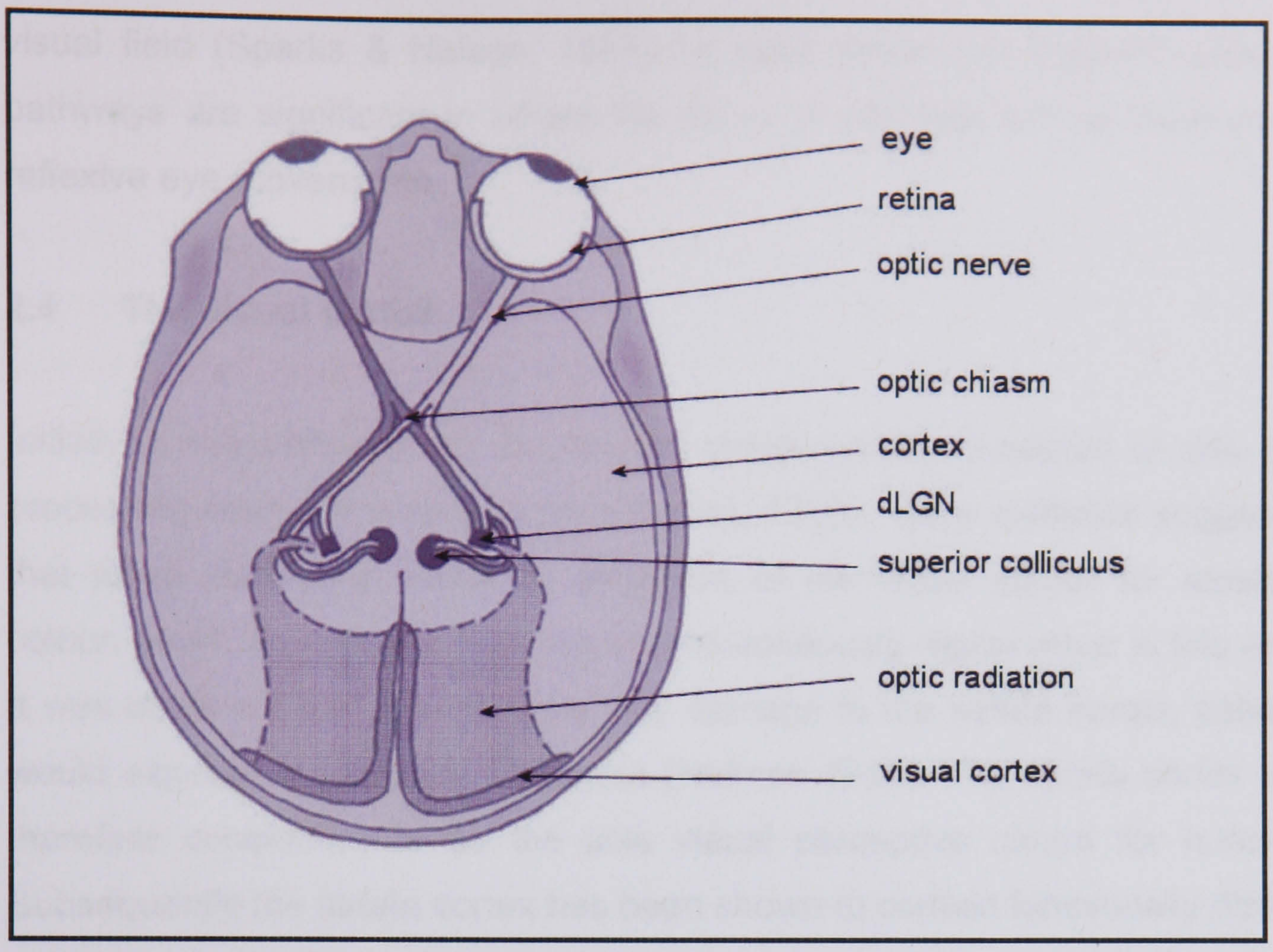


Figure 2.4: The early visual system from retina to the primary visual cortex (adapted from Woolsey, Hanaway & Gado, 2002)

Biases in attention within the visual fields could be the result of activity from superior collicular pathways. Aslin (1981) suggested that the saccadic eye movements of infants appear to be reactionary rather anticipatory, i.e. no experience is required. Neonates will more readily orientate towards the temporal fields of vision rather than the nasal visual field (Lewis, Maurer & Milewski, 1979; Lewis, Maurer & Blackburn, 1985). This suggests that the low acuity subcortical pathways are being utilised in neonatal vision. In adults such a bias might be apparent during the preconscious early stages of visual perception. Evidence to support this comes from studies into supranuclear palsy, where there is degeneration of the basal ganglia and superior colliculi. Supranuclear palsy results in an inability for the patients to orientate their attention towards objects and maintain eye contact (Rafal et al., 1988). This inability to orientate vision and to process eye gaze suggest that the superior collicular visual pathway is vital in not only directing attention but also in reacting to facial or at least eye gaze information. This pathway could therefore be particularly sensitive to high contrast patterned information resulting in the rapid focusing of attention towards specific salient areas of the visual field (Sparks & Nelson, 1987). In early vision the superior collicular pathways are significant in where the focus of attention will be directed via reflexive eye movements.

2.4 The visual cortex

Initially it was believed that the human visual system consisted of only one processing area, the striate cortex (Holmes, 1918). Early evidence suggested that when viewing a scene all attributes of the visual stimuli for example colour, depth, motion and form were instantaneously represented in this area. It was observed that if there were any damage to the striate cortex, patients would experience absolute blindness (Holmes 1945). The striate cortex was therefore considered to be the sole visual perceptive centre for humans. Subsequently the striate cortex has been shown to contain functionally distinct regions and be the preliminary starting point for many other vision related cortical processes (Schiller, 1986; Zeki, 1978).

The signals from the LGN are passed onto area V1, the primary visual area, of the cortex. Evidence from ERP studies suggests that visual information reaches area V1 between 40ms and 60ms post stimulus presentation (Bullier, 2001, 2003; Thorpe & Gautrais, 1996). Up until this point the processing of visual information is a unidirectional flow of information, i.e. a feedforward mechanism. However post V1 the information appears to enter a re-entrant form of processing consisting of repeated feedback and feedforward transmission of information regarding the perceived stimuli (Rolls & Tovee, 1994; Rolls, Tovee & Panzeri, 1999). Up until this point the information picked up by the retina is not made consciously available. However, any interruption to visual processing prior to the information reaching visual areas post V1 can impair the later stages of visual awareness including recognition and reaction. Methodologies such as masking, which interrupt the visual processing of one stimulus by the rapid presentation of a masking image, allow for the exploration of information made available at these early stages of visual processing. In both macaques and humans the V1 and V2 areas appear to be active for all stimuli presented within the field of vision, this suggests that these areas are crucial for all subsequent visual processing (Zeki & Bartels, 1998; Zeki et al., 1991; Zeki, 1978).

In area V1 the information from both the eyes are integrated and the basic information regarding the orientation and contrast of visual stimuli are processed (Hubel & Wiesel, 1967, 1968). Post V1 there are several areas identified as being of specific importance in the cortical processing of visual stimuli, these include the areas V2, V3, V4 in the extrastriate cortex and further areas within the non-striate cortex. Zeki et al. (1991) showed that the lingual and fusiform gyri (area V4) are associated with colour, and that motion is processed within the V5 area. Areas V2 and V3, areas associated with depth and texture perception, have been implicated in the filling in of the blind spot (de Weerd et al., 1995). These areas are therefore of significant interest in the processing of visual patterns and patterns within natural scenes.

The detection of texture, chromatic, spatial frequency and depth all play an important role in the construction of superordinate perceptual units, i.e. global properties of a stimulus, and the subordinate perceptual units, i.e. the local features of a stimulus (Palmer & Rock, 1994: see Figure 2.5). These units can then be extrapolated to fill in the blind spot and provide information to higher levels of visual processing such as object/ pattern recognition and spatial awareness. The areas of V1 to V4 can therefore be associated with the creation of pattern specific perceptual units that contain depth, texture and spatial information. These units can then be analysed further by either reorienting attention or by binding this information together in a way that can be conceived as "pattern recognition units" (Bruce & Young 1986). These pattern recognition units can then be utilised to form associations and identification at higher stages of visual processing (see Figure 2.5). The binding of depth, chromatic, texture and spatial information into pattern recognition units could be the result of stimulus induced gamma activity within the visual cortices. This activity occurs with a frequency of approximately 40Hz, and in stimulus induced gamma activity is observed between 200-400ms after visual presentation (Münte & Heinze, 2003; Tallon-Baudry et al. 1997; Tallon-Baudry & Bertrand, 1999). This post stimulus gamma activity has been associated with the perception of objects, e.g. Kanisza figures (Tallon-Baudry et al. 1997) and implicated in face perception 230ms post stimulus presentation (Rodriguez et al. 1999).

Damage to early areas, such as the retina, LGN and primary visual areas can result in total blindness, disconnecting the visual system from higher brain functions. However, variation in the severity of the damage to the primary visual area provides evidence of the role that the primary visual areas play in the experience of vision. For example some patients who possess scotomas in area V1 cannot consciously see objects presented within the area of the damage, however the patients are able to track objects presented within these areas and subsequently use information from the object. Although the patients are not aware of the stimuli presented within these areas they still have access to information that can be utilised in grasping objects, tracking moving lines and in the successful completion of priming and forced choice experiments (Cowey & Stoerig, 1991, 1995, 1997; Kentridge, Heywood & Weiskrantz, 1999; O'Shaughnessy, 2003).

This evidence suggests that area V1 is critical for visual awareness but despite damage to area V1 some information is still available for higher processing in blindsight patients. This information could be provided bypassing retinotopic areas of the visual cortex via the superior collicular pathway. This would allow for spatial awareness without object awareness as only the where pathway is being utilised (Cowey & Stoerig 1991, 1995, 1997; Kroustallis, 2005; Tong, 2003).

Beckers and Zeki (1995) suggest that the magnocellular pathway might connect from the LGN direct to the V5 area as well as the primary visual areas allowing for the use of spatial and reaching behaviours without the ability to see or identify objects, thus explaining the blindsight phenomena via a fast pathway to the parietal areas. However evidence from patients with lesions to other non-striate cortical areas resulting in visual agnosias, show that other areas of the brain are still vital in completing our visual experience (Fahle, 2003; Humphreys, 2001).

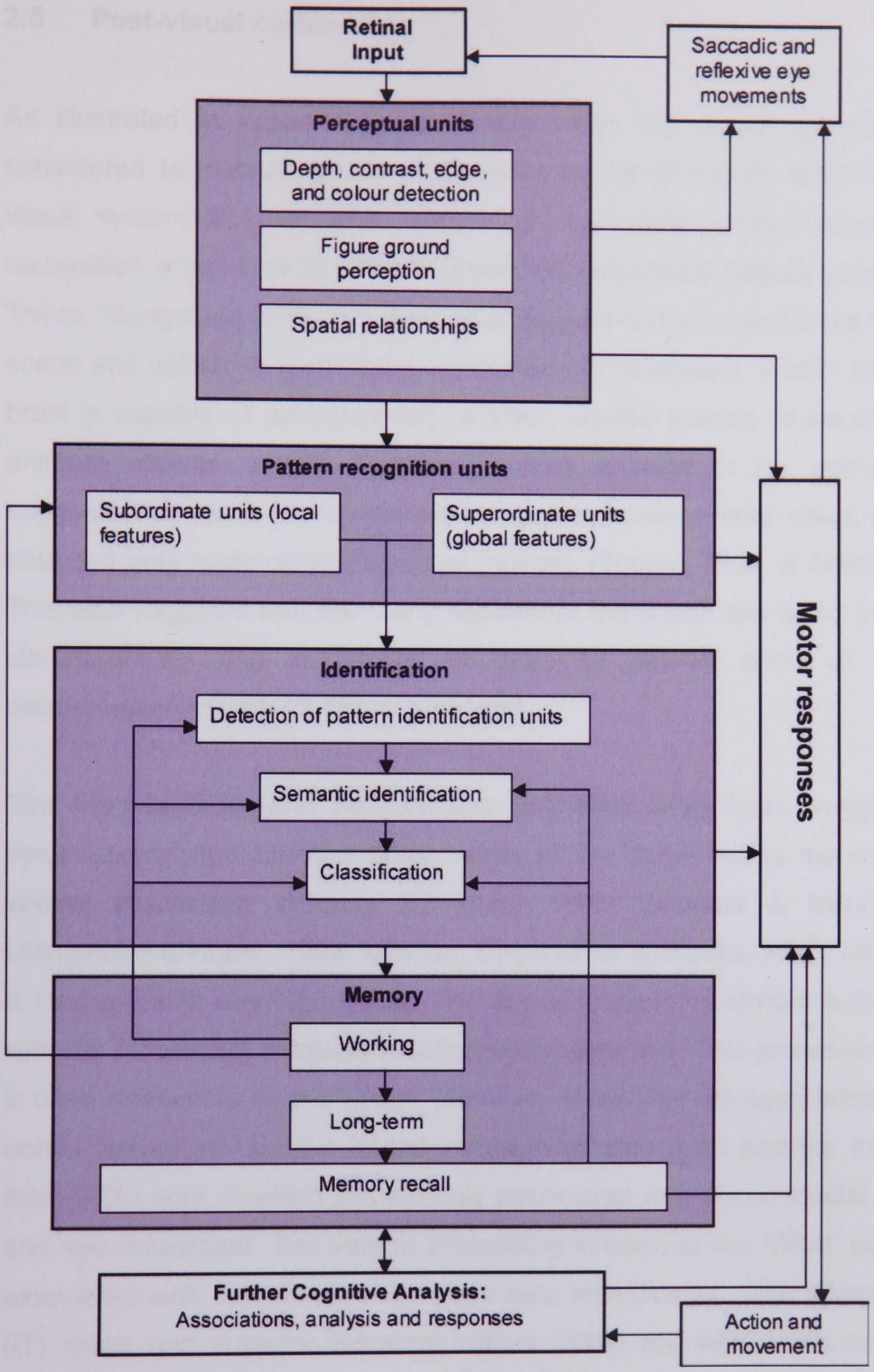


Figure 2.5: A model of visual processing based on Palmer & Rock (1994) and Bruce & Young (1986).

2.5 Post-visual cortex

As illustrated in Figure 2.5 processing within the visual system can be considered to involve the construction of recognition units within the early visual system that are then utilised by non-striate cortical areas for the recognition of patterns at different levels of computation (global versus local). These "recognition units" are then used to guide further attention of the visual scene and utilised in identification and memory processes. Within 150 ms the brain is capable of distinguishing between viewed scenes of inanimate and animate objects, scenes containing either animals or no animals. This suggests that most of the information required from a brief visual glance is obtained very early on in the visual process (Thorpe, Fize, & Marlot, 1996). This also suggests that the many aspects of the scene are being processed simultaneously and in parallel in order to provide such an accurate discrimination in under a fifth of a second.

The magnocellular and parvocellular pathways have been suggested as continuing on into the non-striate areas of the cortex along the dorsal and ventral processing streams (Goodale, 1993; Goodale & Milner, 1992; Livingstone & Hubel, 1988; Mishkin, Ungerleider & Macko, 1982; Ungerleider & Haxby, 1994: see Figure 2.3). The dorsal processing stream is associated with the processing of spatial location and movement. This processing stream is often referred to as the 'where' pathway. Areas that are associated with the dorsal stream include the lateral intraparietal area (LIP) and the frontal eye field (FEF) both of which are strongly associated with visual spatial attention and eye movement. The ventral processing stream, or the 'What' pathway is associated with object recognition and face identification. The inferotemporal (IT) areas and superior temporal sulcus (STS) are associated with object recognition and face perception. These areas are associated with the ventral processing stream. However it is important not to assume complete functional separability of the two pathways, as there is significant communication between the two systems at all levels enabling a rapid fully interactive visual experience (Harries & Perrett, 1991).

Post striate vision involves interactive processing with saccadic eye movements and attentional processes directing the focus of attention and actively selecting the information picked up from the environment that will be processed, reanalysed and reinterpreted. However these later stages of visual perception show apparent specialisation in function. This leads to the idea of specific modules for the processing of specific stimuli. For example in the perception of faces a distinct set of neurons can be identified within the macaque cortex that respond specifically to different profiles of faces (Desimone, 1991).

However, this does not mean that there is a specific module waiting to be activated for the sole identification of every new stimulus encountered. The perception of faces is not a totally localised process but requires input feedback and feedforward to many other different areas of the cortex. Certain areas of cortex might prove to be activated by configurational properties of an object rather than categorical identification and therefore show a bias towards particular stimulus types. For example face perception can be analysed both in terms of configuration (Farah et al., 1998) and expertise (Tarr & Cheng, 2003). With increased use of functional magnetic resonance imaging (fMRI) and the identification of areas of the cortex that appear to respond exclusively to a particular isolated stimulus there is a tendency to oversimplify the location of brain functions (Dobbs, 2005). Nonetheless it is still feasible to identify neuroanatomical pathways and regions within the visual streams that may play a major role in pattern perception. The following sections discuss the perception of symmetry and facial patterns with reference to neuroanatomical evidence.

2.6 Neuroanatomical evidence for symmetry perception

Neuroanatomical evidence suggests that the detection of reflective symmetry in humans might not be an automatic early visual process but the result of processing within extra-retinotopic areas. The lateral occipital cortex within the ventral processing stream, an area already associated with shape detection (Malach et al., 1995), has been identified as one such possible neural correlate the detection of reflective symmetry (Tyler, 1999). In an fMRI study of the perception of symmetrical dot patterns versus random dot patterns a number of cortical areas were identified as being particularly sensitive to changes in reflective symmetry (Sasaki et al., 2005). The areas identified were areas V3a, V4, V7 and the lateral occipital areas associated with object perception. Activity within these areas was stronger for the symmetrical stimuli than the random stimuli. To test whether this was a symmetry effect, the experiment was repeated but with graded stimuli ranging from perfect reflective symmetry to complete randomness. The results suggested that the areas identified did indeed decrease in activity as the images became more random. Further testing highlighted the specificity of these areas for reflective symmetry as activation of these areas was greatly reduced when the stimulus presented was a repeated pattern. This suggests that reflective symmetry detection is not an early visual process occurring preattentively but perhaps a useful part of object recognition. Sasaki et al. (2005) argue that the presence of these neural correlates for symmetry detection and the presence of similar homologues in the macaque cortex suggest a high biological value for symmetry perception in predator and mate searching.

Evidence from visually evoked potentials (VEP) has shown that within the first 120 milliseconds the perception of stimuli is predominantly bottom up with little or no feedback from the extrastriate areas (Lamme, 1995; Oka, van Tonder, & Ejima, 2001). During this time the V1 cells respond to contour shape and symmetry axis detection. This is followed by high level feed forward processing between 120 ms and 230 ms and then by high level top-down processing. Between the 120 and 230 ms range it has been suggested that local features are grouped into perceptual wholes via reentrant connections between the striate and extrastriate areas (Oka, van Tonder, & Ejima, 2001; Sporns, Tononi & Edelman, 1991). The processing of symmetrical stimuli, as previously mentioned, occurs well within this time frame (Barlow & Reeves, 1979; Baylis & Driver, 1994; Locher & Wagemans, 1993). This could suggest that some type of Gestalt grouping could be occurring early on giving the perceptual advantage to mirror symmetry. However as evidenced by fMRI studies the 'symmetry-ness' of mirror symmetry perception appears to involve a number of areas associated with object detection and recognition (Tyler, 1999; Sasaki et al., 2005).

Evidence provided by backward masking experiments has shown that perceptual grouping by proximity takes approximately 87.6 ms while the processing time for grouping by alignment, is 118.8 ms (Kurylo, 1997: see Figure 2.6). Both these times are within the limits of the bottom up processing stream (less than 120 ms) and suggest that these grouping factors occur in the retinotopic areas of V1 and V2. Kurylo used stimuli that consisted of square arrays of dots, participants had to identify whether the dots within the square were grouping in horizontal or vertical lines. The results indicate a slight bias in the identification of the dots grouped by proximity, suggesting this might be a type of grouping that is processed earlier within the visual system. Symmetrical patterns that show proximity to the central axis could therefore be taking advantage of this phenomenon.

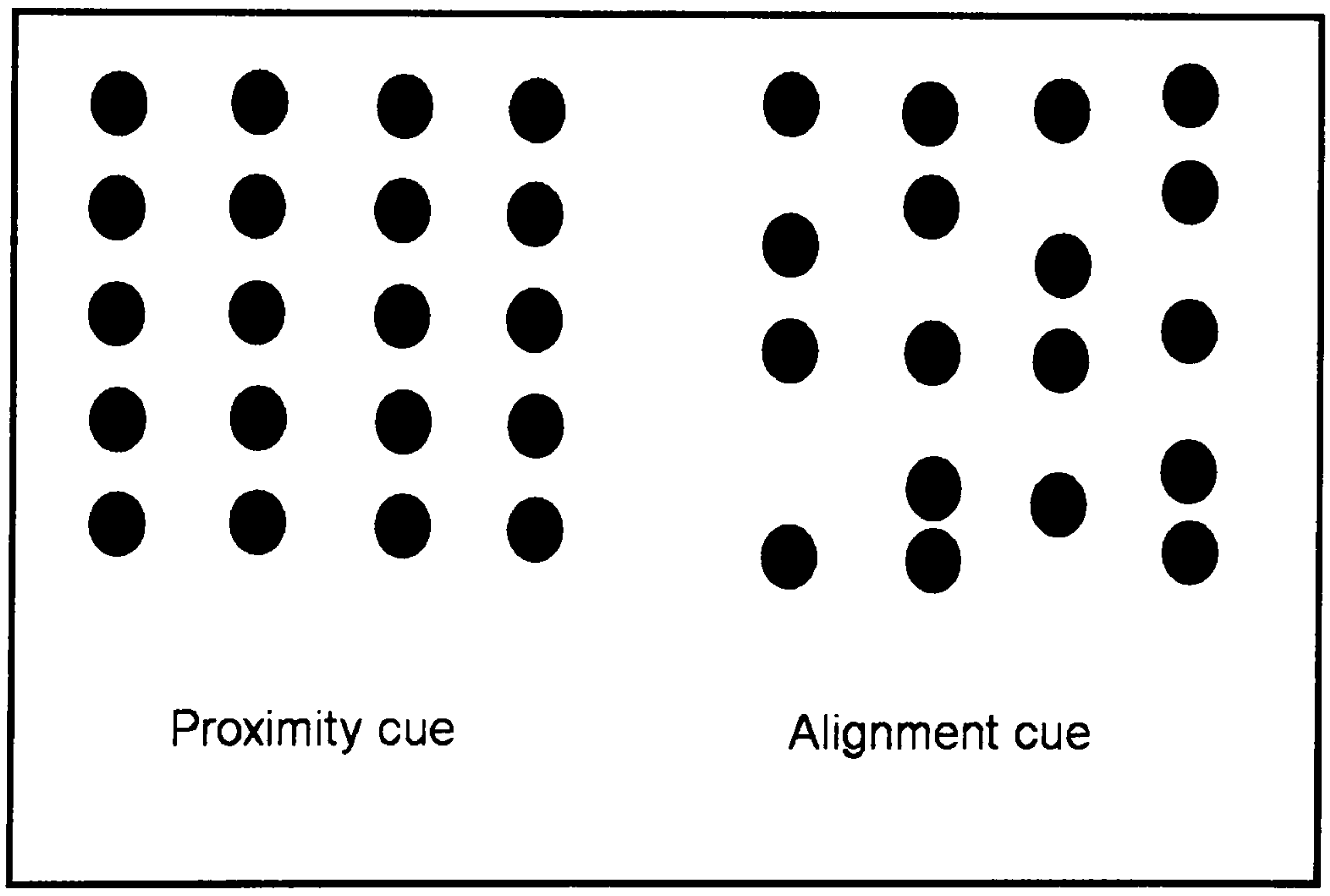


Figure 2.6: Example of grouping by proximity and by alignment as per Kurylo (1997)

fMRI studies have shown that the presence of reflective symmetry has an advantage compared to other types of pattern, i.e. repetition, on the known retinotopic areas of the occipital cortex such as the primary visual areas V1 to V4 (Tyler, Hardage & Miller, 1995; Tyler et al., 1996;Tyler, 1999; Tyler et al., 2005). This would suggest that different symmetry types are not prioritised in early vision. However Tyler & Baseler (1998) noted that images with multiple lines of symmetry differentially activate an area of the middle occipital gyrus on the lateral surface. Areas proximate to this region have been implicated in general object perception (Gilaie-Dotan et al., 2002; Amedi et al., 2002). Therefore this could suggest a common basic process for reflective symmetry detection and general object detection. Although this could be interpreted as suggesting that there is no special processing route for symmetry, the evidence highlights the importance of reflective symmetry in figure-ground distinction (Baylis & Driver, 1995).

The argument for preattentive processing of different symmetries is not clear-cut. Driver et al (1992) report the case of a patient with brain damage centred on the right parietal lobe who could not perceive the left hand side of objects. The patient was able to detect images that are reflected across a horizontal axis and when shown a series of images and asked which shapes were seen as figures against a background he would show a preference for reflective symmetry across the vertical axis as in the normal population. This could suggest an early visual stage involved in symmetry detection prior to the level at which the patient was injured or it could suggest that the information was still available via other feedback mechanisms, perhaps via the 'where' pathway, as observed in blindsight patients (O'Shaughnessy, 2003; Beckers & Zeki, 1995).

2.7 Neural correlates of face processing

Advances in brain imagining especially the high resolution and rapid imaging of fMRI (functional magnetic resonance imaging) have allowed psychologists and neurophysiologists to examine the brain in action while performing a variety of tasks. This technology has opened up new avenues for research into face processing and object recognition. Areas of the occipito-temporal extrastriate regions of the cortex have been implicated in the recognition, identification and processing of face stimuli (See Haxby et al., 2000 for a summary). The main areas that have been identified as being of importance in face detection are the superior temporal sulcus (STS), the fusiform gyrus, and inferior occipital gyri. One population of cells has been identified as responding exclusively to faces has been termed the fusiform face area or FFA (Kanwisher et al., 1997; McCarthy et al., 1997; Sergent et al., 1992), this area is not only implicated in face detection but it has been implicated with expression (Ganel, Goshen-Gottstein & Goodale, 2005), eye gaze detection (Hoffman & Haxby, 2000) and therefore suggested as responding to configural aspects of face processing. Post face detection, the hippocampus and left prefrontal cortex have been implicated in the memory encoding of faces and the right prefrontal cortex in face recognition (Haxby et al., 1996). The evidence suggests that there are dissociated processing areas with specific functions for face detection, recognition and memory encoding.

However despite evidence for face specificity in certain areas of the cortex there is growing evidence that some of these areas are not face specific. Tarr & Cheng (2003) suggest that visual expertise, the kind of expertise that is usually only attributed to faces, might have evolved as a specific response to the pressures of human social groups. Within such groups there would be a need to remember the faces of conspecifics and information relating to their behaviour, personality and activities. Although usually this kind of expertise is face specific there is evidence that expertise in areas such as bird watching, car recognition, and 'Greebles' (novel non-face objects), activate similar areas used for expertise in face recognition (Tarr & Cheng, 2003; Gauthier et al., 2000; Gauthier & Tarr, 1997). The evidence from Greebles, 3-dimensional characters, car and bird experts suggest that areas such as the FFA that are associated with expertise in face perception could also be used for expertise in the recognition of other stimuli. The FFA is therefore sensitive to facial configuration but these configurational schemas could also be applied to non-face objects.

Despite the growing evidence for specific face processing areas within the cortex, the use of fMRI technology has recently come under some criticism for over modularising the human brain (Dobbs, 2005). With areas of the brain being identified as utilised in a variety of different tasks, emotions, and perceptual criteria there is a danger of over simplifying what is occurring in the cortex and attributing meaning inappropriately to cortical areas. For example although there are highly distinct areas of the brain that are used for face detection and even neurons that fire in response to very specific face stimuli (Perrett et al., 1992; Perrett et al., 1985), this can lead to an oversimplification of what it is to see a face. Ishai et al. (2000) demonstrated that when perceiving objects such as a chairs, houses and faces a large number of areas across the occipital and temporal regions are involved and that object detection and recognition is not limited to only small selective patches of cortex. However it has been shown that the representation of faces is less extensive across this distributed system, again highlighting the expertise and salience of facial stimuli (Ishai et al., 2000; Ishai et al., 1999).

Evidence from ERP studies has provided several possible time courses for the process of face recognition, these include the distinction between novel and previously seen faces at around 50ms post stimulus presentation (Seeck et al., 1997), and activity of face sensitive neurons in the temporal lobe at around 80 – 100ms (Oram & Perrett, 1992). This suggests that top down effects occur early in the visual processing of stimuli. An early recognition of face stimuli would benefit the subsequent feed forward division of labour in face processing.

A summary of the time course of visual processing with suggested time frames for the early processing of face and object stimuli is presented in Figure 2.7. Further evidence regarding the neural correlates and the process of face detection and recognition can be found in studies of patients suffering from prosopagnosia and patients suffering from brain lesions.

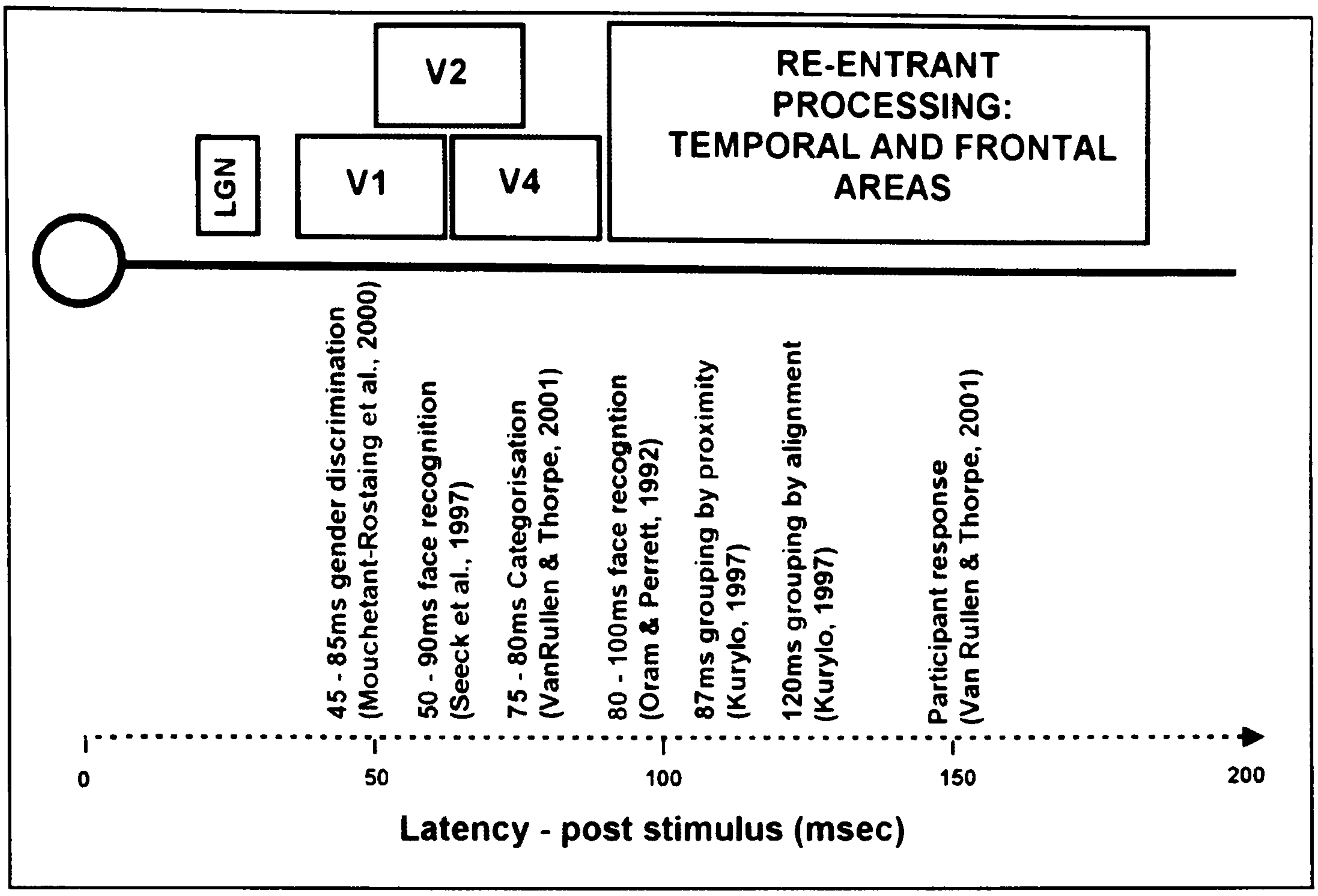


Figure 2.7: Schematic summary of the time course of visual processing with regard to face processing and perceptual grouping

2.8 Prosopagnosia and face detection

Prosopagnosia is the inability to identify faces and when literally translated from the Greek means without *knowledge of faces*. Many of the patients suffering from this condition are aware that they are looking at a face but do not know who they are looking at, however symptoms vary according to which areas of the cortex has been damaged. Despite impoverished face recognition prosopagnosic patients often have normal or near normal object recognition suggesting that the damage to the brain is localised to some aspect of face processing (Moscovitch, Wincour & Behrmann, 1997; de Haan, 1999). Therefore patients suffering from prosopagnosia provide a vital clue in piecing together which brain areas are involved in face perception and what these areas actually do and how they relate to theories of face perception. Bodamer (1947) claimed that prosopagnosia was evidence of a face only processing system as patients could not identify faces but could identify objects.

De Renzi (1986) reported cases where prosopagnosics were given object recognition tasks that were comparable to that of face recognition tasks, for example the participant would have to spot their own car from within a car park filled with other similar cars or spot their own wallet from a pile of other wallets. This kind of task therefore had similar properties to a general recognition task in that the participant had to identify something on more than just object recognition but also attach meaning to the object that distinguishes it. This led De Renzi to support the ideas of Bodamer in suggesting that there was something particularly special about face perception.

However, prosopagnosic patients with damage to the FFA have been recognised as suffering from deficits in their perception of the spatial configuration of facial features (Barton et al., 2002; 2003). Barton et al. (2002) examined changes in the spatial configuration in terms of a geometry context effect, based upon the facial geometry, by perceiving the eyes and mouth as the apices of a triangle. Any distortion in distance between any of the elements would have a knock on effect on the shape of the triangle. In the prosopagnosic patients studied they noted that there was little detection of these changes when compared with normal participants. One of their prosopagnosic patients with bilateral temporal lesions but no damage to the FFA performed well on the tasks. This suggests that the FFA is perhaps a specialised face configuration area.

Further evidence for an exclusive face configuration processing module or domain comes from R.P., a male prosopagnosic patient. In a series of experiments R. P. was asked to perform a pair-matching task. The experiment involved being shown faces and shoes in upright or inverted positions and asked to decide if a sequential image as the same or different to the first. R.P. showed better performance for faces in the inverted position compared with those that were upright. This suggests that R.P. was unable to pick up on the subtle configurational aspects of face processing. However his object recognition skills, and face identification, in terms of inverted faces, are still intact with performance on the shoe task very high (Rouw & de Gelder, 2002). Another patient L.H. showed impoverished performance in a similar test for upright objects and upright faces but improved performance for inverted faces and objects. This suggests that there might be some configurational processing in common for both faces and objects (de Gelder & Rouw, 2000).

In a variation of the expert effect in face processing, Farmer W.J., who became prosopagnosic after an ischaemic incident could identify sheep more accurately than human faces suggesting that damage had been done to the human face recognition areas of the brain and that nonhuman faces were categorically processed differently (MacNeil & Warrington, 1993). This could be partially due to the configuration of the faces, as the features present within the sheep face are arranged differently to that of a human, with eyes very far apart, long snout, and no distinct emphasis of mouth features.

Although configuration plays a very important role in the visual processing and recognition of faces, it could be argued that some features are more visually important than others. Barton, Keenan and Bass (2001) examined the spatial relations of features in a discrimination of changes test. The changes incurred involved changes in eye position by moving the eyes apart by 1 to 8 pixels, changes in eye colour and changes in the position of the mouth. The images were shown for 1, 2 or 4 seconds and in an upright face condition or an inverted face condition. In the upright face condition participants identified all changes within 2 seconds. However when the faces were inverted changes occurring to the mouth position were particularly difficult to discriminate. Eye colour changes were relatively unaffected. In general changes to the eyes either in colour or distance between the eyes were easier to detect than changes to the mouth. Barton et al. (2001) suggested that the saliency of stimuli had an effect on the accuracy of discrimination. If the mouth trials were repeated more frequently, making the mouth the more salient feature, then discrimination improved significantly. They suggest that there is reduced discrimination of changes to the less salient features. This therefore suggests that in social interaction the eyes are a particularly salient feature in the perception of facial patterns.

2.9 Neural correlates for eye gaze

The importance of the eyes in face perception could suggest that there are distinct eye processing areas within the cortex that allow for the rapid processing of the stimulus. Perrett et al. (1985) identified cell populations in the Superior Temporal Sulcus (STS) of macaques responsive to gaze directions, independent of head orientation. Similarly Jellema et al. (2000) identified populations of cells within the anterior areas of the STS in the macaque temporal lobe that respond specifically to the intentional performance of actions. These populations of cells responded to the sight of an individual reaching for an object but only when the agent is attending to the object. Similar studies with humans elicit activation of cells in the posterior STS (Hooker et al., 2003; Puce et al., 1998), the fusiform gyrus, right parietal lobe, right inferior temporal gyrus, middle temporal gyrus (Wicker et al., 1998), and the amygdala (Brothers & Ring, 1993, 1990; Kawashima et al., 1999). These results are bolstered by the finding that damage to the STS and the amygdala result in a significant deterioration of eye gaze determination (Perrett et al., 1985, Young et al., 1994). The involvement of the amygdala further implies the emotional significance of eye gaze in social life and as a social pattern.

The identification of the cortical areas associated with pattern perception, face perception and eye perception highlight the apparent modularity of the visual system with specific processing systems for specific visual inputs (Fodor, 1983). However, the early stages of visual processing for all stimuli types are similar in that depth, texture, and orientation all have to be defined early on in the primary visual areas prior to any specialisation or modularisation of function. The following section describes different approaches to how visual stimuli are perceived and the implications for studying pattern perception.

2.10 Top-down, vs. bottom-up processes in pattern perception: theoretical overviews

The processing of visual information has been largely described in terms of a unidirectional approach whereby information from the stimulus is picked up processed, analysed and identified. However, this does not necessarily explain how a pattern or scene is actually perceived. The process of perception can be both bottom-up and top-down in nature. Bottom-up processes are ones that are data driven, i.e. are influenced solely by the sensory input. Top-down processes are those that are driven by past knowledge or are conceptually driven (Eysenck & Keane, 1990). From the neuroanatomical evidence it is evident that the early non-cortical stages of visual processing are bottom-up, however, with re-entrant processing it becomes difficult to ascertain to what extent the later stages are bottom-up or top-down. Examples of bottom-up theories and top-down theories of visual perception are presented and the implications for the interpretation of visual patterns are examined in the following section.

Gibson's (1979) theory of information pick up suggests that all the information regarding the properties, texture and patterns of an object are present in the optic array. This information is picked up in a direct fashion with little or no further processing in the brain. Gibson rejected the idea that there is an internal representation of visual scene within the cortex. This theory is mainly a bottom-up approach to perception as there is little role of the higher brain functions in the perception of the visual world. The higher brain functions are reconsidered as a resonator of the environmental energy and a method for redirecting the act of perception around the environment and not representation.

Conversely, Gregory (1972) suggests that perception is the end product of the interaction between the direct pick up of visual stimuli and the internal hypotheses, expectations and knowledge about the scene. Therefore, perception is highly pro-active process that requires a significant top-down approach and is prone to error. This type of constructivist theory puts the emphasis on the inferential processes and reinterpretation.

Marr (1982) recognised the importance of Gibson's work especially in terms of reconnecting the visual system within the environment, however he was critical about Gibson ignoring the higher brain functions as a form of information processor and reanalysis mechanism. Marr suggests that the information picked up by the eyes has to be interpreted at higher levels in terms of depth, orientation, colour, edges, grouping and distance. These functions he argued have to be carried out within the cortex and the act of seeing is a combination of information pick up and reinterpretation of this information within the cortex. Marr suggested that any machine that is carrying out an information-processing task must be understood in terms of three levels, computational theory, representation and algorithm and hardware implementation. Marr's theory is predominantly based upon bottom-up processing where visual perception is constructed in a hierarchical manner from the properties of the stimulus. However, Marr does acknowledge that top-down functions play a significant part in the interpretation of the images presented within a scene especially with regard to the perception of visual illusions such as the Muller-Lyer or Hering illusions.

Similar to the direct perception theory of Gibson (1979), O'Regan and Noe (2001) argue that visual awareness is the culmination of sensorimotor skills and that there is no next level of visual integration where the visual scene is bound together and made available to consciousness. Instead the act of controlling the visual system is the act of visual awareness and the synchrony of activity within the brain is why the scene appears bound, i.e. the outside scene is never broken down and reconstructed as in the internal theatre/ spotlight scenario. However, unlike Gibson's theory, top-down processes can influence perception in that it is the control of the system that is the act of seeing or being aware, therefore top-down processes and expectation can interrupt the information pick up and create illusory constructs.

In reality both bottom up and top-down approaches are essential in the perception and cognition of visual stimuli. A system based solely on bottom-up processing would be hazardous to the viewer, as ambiguous visual information would not be interpreted properly. However, an over reliance on top-down processing would mean the viewer would not be perceiving the real nature of a scene but only a manipulated perceptual construct. When the conditions are optimal then bottom up processing would be advantageous in reducing the amount of time processing and analysing a scene. However, top down processes are essential in reducing the interaction time with stimuli by extrapolating the available information.

Pattern perception can be considered as being processed by either bottom-up or top-down functions. From the bottom-up perspective the properties of the stimulus are the criteria that make one type of pattern more salient than another. For example in the holographic models of symmetry perception (van der Helm & Leeuwenberg, 1996) it is the information contained within the stimulus that is important in the time taken for visual processing, either serially or in parallel. From the top-down perspective, repeated patterns can gain an advantage via information redundancy, whereby the visual scene can be extrapolated without direct perception of each individual element. The top-down approach to visual perception also provides an explanation for the perceived modularity of the visual cortices whereby selective areas are activated for faces, objects or reflective symmetry. These areas will provide a rapid method of identifying and recognising objects, and as with the suggestions of Gregory (1972) these perceptions are prone to error and the top-down analysis can explain these instances when a face or pattern is incorrectly recognised.

As types of pattern, faces are a special case in that not only do faces contain symmetrical/ configural information they also impart intentional and emotional information. The philosopher Merleau-Ponty (1960) was acutely aware of the dichotomy of being an intentional agent and that of perceiving others as perceptual agents. His suggestion was that when perceiving another individual not only is that person being seen as an object, a bottom-up process, but the observer also imparts the same qualities as themselves onto this agent creating a set of expectations about how they will behave, a top-down process. However, even for facial patterns the early stages of pattern processing within area V1 are predominantly bottom-up in nature so it would be expected that interruption of visual processing during these stages would have a similar effect on faces as on other pattern types.

Masking methodologies allow the interruption of processing of visual information and are thus a potentially valuable tool for ascertaining the processing intervals for various aspects of visual stimuli. In this way the relative influence of early, bottom-up vs. later, top-down processes can be determined. However, when examining faces there are always preconceptions and therefore a likelihood that top-down influences could interfere with masking procedures. Therefore when interpreting facial stimuli it is necessary to consider the top-down processes and the perception of faces as intentional beings. The choice of methodology is discussed further in the methods chapter. However, prior to this the top-down influences involved in pattern perception are considered via a series of pilot studies.

Chapter 3: Pilot studies

The main questions within this thesis involve how patterns are perceived during early vision and what factors influence the saliency of different pattern types prior to extensive re-entrant and attentive processing of the stimuli. However, it is equally important to briefly examine how patterns and faces are perceived at the other end of the visual processing timeline. The way that people approach a problem such as defining what a pattern is can provide clues as to any possible top-down perceptual biases that could influence early visual perception. The following two pilot studies provide a viewpoint on what characteristics are considered most important in each definition, one study defining patterns and one study defining faces.

3.1 Defining patterns

When considering what constitutes a pattern, interpretations are either functional in terms of implying a design and redundant information or are largely personal and subjective. The term pattern can therefore be interpreted in a variety of conflicting ways. Therefore, when undertaking a study that involves the use of such a term as 'pattern' it is necessary to first consider what these subjective interpretations could be. The Oxford English Reference Dictionary 2nd edition (1996) provides three contrasting descriptions of what defines a pattern.

1) A repeated decorative design on wallpaper, cloth, a carpet etc.
2) A regular or logical form, order or arrangement of parts.
3) A random construction of shapes or colours.

Each definition provides a different perspective on the problem of studying patterns. The first definition suggests that patterns are repetitive and of largely aesthetic value. The aesthetic value is important, as images that are more salient are likely to prove more pleasing to the eye, i.e. attractive patterns will capture attention. In the discussion of symmetry types in chapter 1 it was noted that body shapes with good reflective symmetry were preferentially selected during mate choice among birds (Möller, 1990, 1992). The second definition describes patterns in terms of logical rules and styles of arrangement. This suggests a formal, deliberate arrangement and the mathematical properties of the stimuli. The third definition suggests a more chaotic and perhaps natural definition of what could be perceived as a visual pattern, although the definition does infer construction so can be interpreted as bearing some rudimentary organisation.

As suggested by Falk (1991), people possess a general preconception of what constitutes a pattern even within random elements. The participants in Falk's study exhibited a bias towards perceiving "randomness" as an array of elements that are more evenly spaced than chance alone would allow, i.e. as a pattern. Conversely this suggests that the participants believed that truly random grids, where some elements are aggregated together, possessed order or form. This highlights a bias within human perception towards selecting and picking out regular form from background noise. By applying preconceived patterns to otherwise random stimuli is a way of extracting information about the natural environment.

Gestalt theories and simplicity theories suggest an important role for figural goodness in the perception of objects and patterns (Chater & Vitanyi, 2003; Handel & Garner, 1965; Olson & Attneave, 1970; Porthos & Ward, 2000; Wertheimer, 1923). Handel and Garner (1965) illustrated figural goodness in terms of the number of possible variations of an image that can be created by either rotation or reflection. This method utilises a logical rule and formalises figural goodness in terms of approaching perfect symmetry. When perceiving a pattern this type of figural goodness might be important in both identifying repeated elements and a preference for reflective symmetry. Patterns that possess several lines of symmetry will have high figural goodness as they will have fewer possible variations when reflected or rotated. While patterns that are repeated will have more possible variants but will still possess fewer elements than a random pattern. Therefore, the information redundancy present within repeated patterns may increase the figural goodness of an image.

The theories of figural goodness suggest a viewpoint in which good form, and therefore patterning, is correlated with greater ease of visual perception. In the following study figural goodness is examined in terms of how many variants a pattern possesses after reflection and rotation. This provides a measure of the information redundancy in the stimuli, as patterns with a low number of variants, i.e. one or two, can be described with less information than those that have multiple numbers of variants. Therefore, there is greater entropy in the stimuli that possess a higher numbers of variants, as there are more possible ways to describe the image, i.e. the uncertainty within the image has been increased. This measure provides a scale from randomness to perfect symmetry.

As one of the key questions in this thesis regards whether different symmetry types, in particular repetition and reflection, possess different properties that are processed differentially within early vision, both types of symmetry were included in the test stimuli for this pilot study. In addition to symmetry type, the complexity and intricacy of the patterns were assessed, to see whether the global factors of shape and figural goodness, or whether it is the local interaction of smaller elements that are preferentially perceived as being pattern-like. As discussed in Chapter 1, repetition is suggested as being processed serially at the local element level while reflective symmetry is suggested as being processed at a more global object based level. Therefore repeated patterns may be perceived as being more pattern-like due to the repetition of individual elements, or conversely reflective symmetry may provide a saliency and regularity of form that might prove preferential.

When defining a pattern the context within which a pattern is presented is also important, for example in nature a repeated pattern can provide either camouflage or alternatively a conspicuous signal (Figure 3.1). The constituent elements of the pattern and the context within which they are presented will therefore dictate whether a pattern is perceived as being conspicuous and not the pattern category, i.e. repetition or reflection. However, as illustrated in Figure 3.1, repeated patterns exhibit many background qualities and help to break up an outline, while symmetry may highlight the form of an animal. However, the relative contrast and chromatic properties of an image will have a major effect on how a pattern is perceived and interpreted.

Figure 3.1: Patterns present in nature, which serve to either break up an outline (e.g. the repeated patterns on a giraffe) or to highlight a feature and act as a signal (e.g. the repeated and reflected properties of the tail of the ring tailed lemur).

In selecting an appropriate stimulus for this pilot study it was particularly important to select a type of image that was accessible to all the participants. In this study a checkerboard stimulus was used as this represents a stimulus that is not alien to the participant but does provide sufficient flexibility to manipulate the stimulus properties. The following test involved members of the general public answering a one-page questionnaire that asked them to rate a series of ten checkerboard stimuli, similar to those used by Victor and Conte (2005), in terms of how "pattern-like they perceived the image to be. The participants were then provided with a chance to define their perceptions of what constitutes a pattern.

3.2 Method

3.2.1 *Participants*

An opportunistic sample of 130 people agreed to take part in the test. The sample was obtained from members of the public attending the Cheltenham

Science Festival 2003 (Cheltenham, Gloucestershire). Participation in the experiment was voluntary and all responses were anonymous. All participants were aged 18 years old or over.

3.2.2 *Apparatus and Materials*

Two questionnaires were produced (see Appendix B). Each questionnaire contained eight 10x10 grids containing a variety of patterns (see Figure 3.2 for examples). Each pattern consisted of an arrangement of black and white squares. Questionnaire 1 contained a variety of patterns based on one simple non-symmetrical unit that was 5x5 squares in size. This unit was repeated, rotated, reflected or randomised by adding noise within the 10x10 grid. Questionnaire 2 consisted of a variety of patterns that were either simple or complex in structure. Complexity in this example refers to patterns that are composed of multiple single square elements, where as simplicity refers to patterns made from larger elements 2x2 squares in size (see Appendix B). On both questionnaires grids were designed to reflect figural goodness in terms of the number of possible variations that can be obtained by rotation and reflection these are 1, 2, 4 and 8 variations (Handel & Garner, 1964: see Figure 3.2). Therefore patterns containing symmetry across both the vertical and horizontal axis would possess one variant as when rotated or reflected the image would remain the same. For patterns with only one line of symmetry there would be four variants and for repeated patterns and random patterns there would be eight possible variants (see Figure 3.2). Patterns that contain a fewer number of variants are suggested as possessing greater figural goodness.

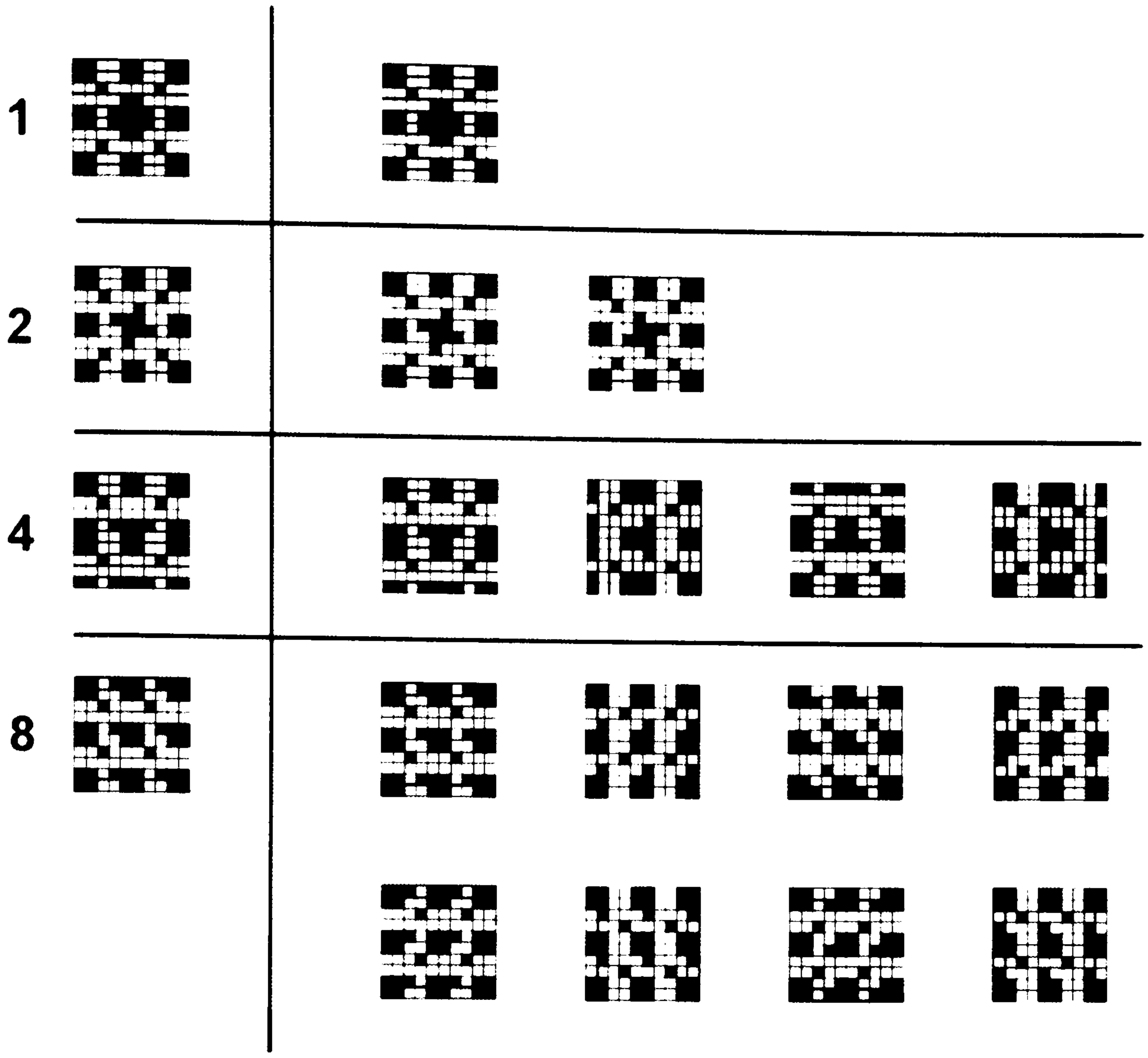


Figure 3.2: Examples of the different number of variants that each pattern possesses. The examples are taken from the questionnaire. 1 variant = reflection across both the horizontal and vertical axis, 2 variants = rotation, 4 variants = reflection across one axis, and 8 variants = repetition (or random) patterns with no axes of reflection.

At the bottom of each questionnaire there was a space where participants were asked to either put a tick beside the word or words that they felt best described the term pattern and room for them to add their own personal definitions (Figure 3.3).

➢ Symmetry (e.g. rotation or reflection) ☐
➢ Reflection ☐
➢ Repetition ☐
➢ Novelty ☐
➢ Pleasing to the eye ☐
➢ Complexity ☐

Other (please specify)......................................

Figure 3.3: The choice of defining words from the bottom of the questionnaire.

3.2.3 *Procedure*

Participants were requested to rate eight patterns presented to them, the patterns were arranged randomly on the questionnaire to prevent any ordering effects. The participants were required to rate the stimuli on a scale of 1 to 5, where 5 represented grids that they considered to be the most pattern like grid and 1 represented grids that they considered to be the least pattern like. Four of the patterns contained repeated or reflective elements that were disrupted by noise. The other 4 patterns contained repetition or reflective symmetry and had 1, 2, 4 or 8 possible variations after rotation and reflection (Figure 3.2). Examples of patterns were present around the test area in the form of posters, see Figure 3.4 for examples of the patterns. These images were selected to reflect the definitions presented by the Oxford English Dictionary and were to provide a visual reference for the participants.

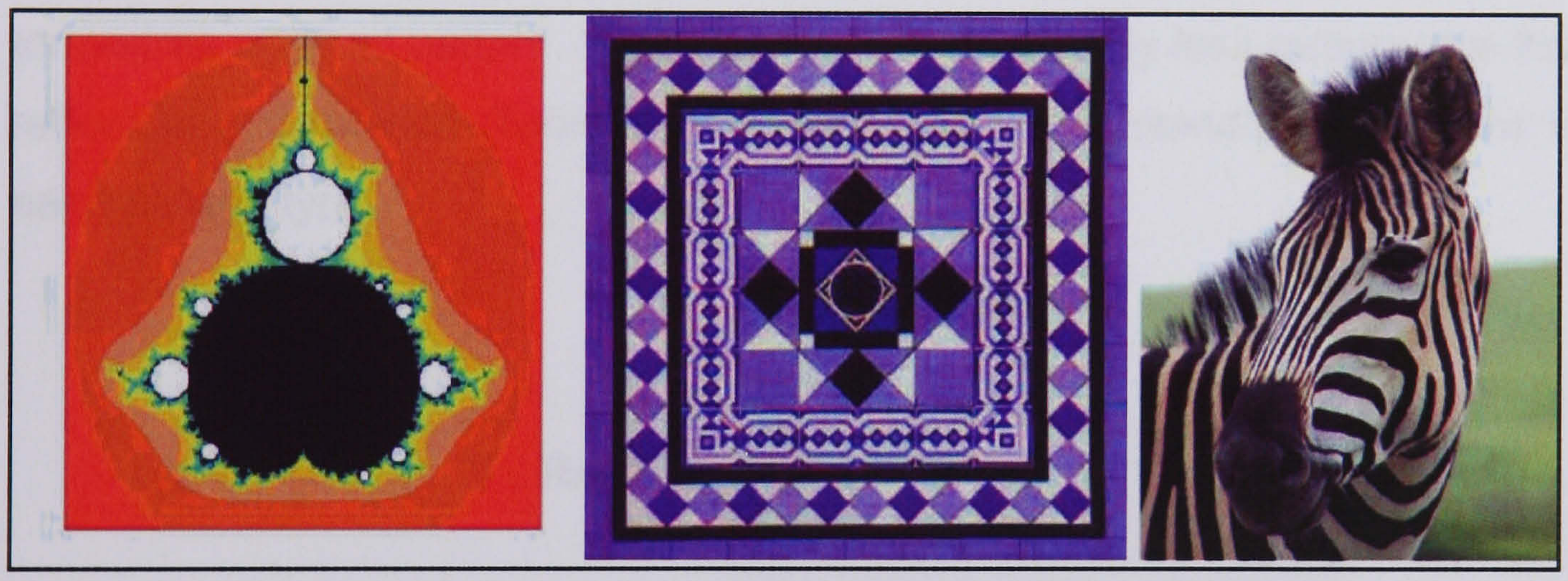


Figure 3.4: Examples of patterns present around the test area, a randomly generated Mandelbrot set, a tiled floor design and a zebra containing regular logical forms: zebra picture taken from www.wildlife-pictures-online.com

After rating the images the participants were asked to place a tick beside the statements that they felt best described their perception of what a pattern is. These included, symmetry, reflection, repetition, 'pleasing to the eye', complexity and novelty. After completing the questionnaire participants were given a handout that contained the dictionary definitions and were debriefed (see Appendix I).

3.3 Results

3.3.1 *Type of symmetry*

The data comprised of the participant ratings (on a scale of 1 to 5) for each pattern type and the frequency with which a particular definition was selected. All data were analysed using a non-parametric test, as the data were not normally distributed and unequal sample sizes. There was a significant difference between the pattern-ness ratings for the different pattern types, repetition, reflection, patterns containing reception and reflection, rotation and patterns with added noise ($\chi^2 = 278.439$, df = 4, $p < 0.001$). Figure 3.5 shows that there was a trend towards ranking patterns that contain both repetition and reflection as being most pattern-like. Those patterns that contained added noise were ranked as being the ones that were the least pattern-like. This suggests that there is a strong aesthetic bias in defining what should be termed as a visual pattern. Repetition was rated slightly less pattern-like than reflection and rotation. Table 3.1 contains the means, standard deviations for each pattern type.

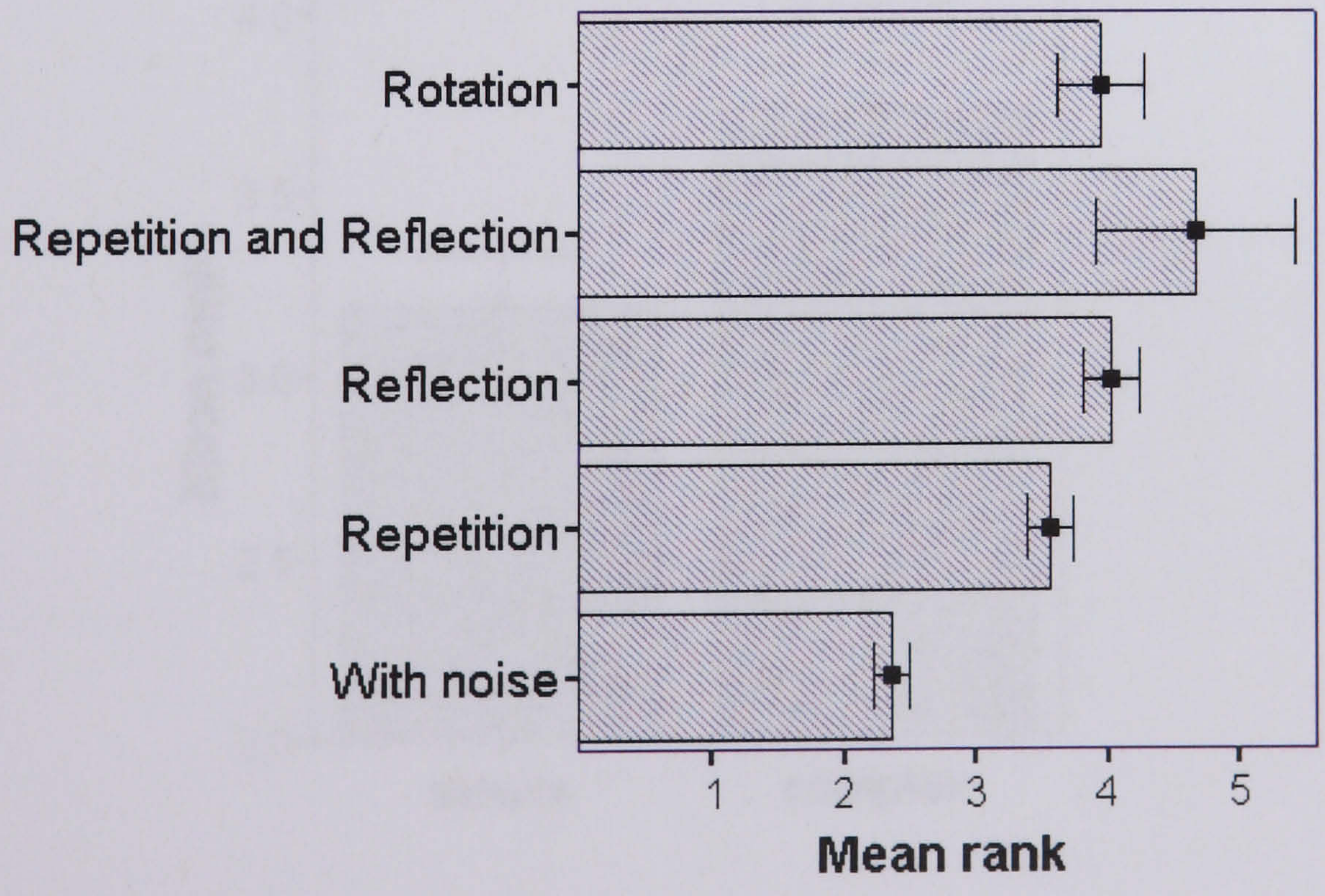


Figure 3.5: The mean ranks for the 5 different pattern types: 1 = not pattern-like and 5 = very pattern-like. Error bars represent the 95% confidence intervals.

Table 3.1: The means, standard deviations (SD), and the frequency with which a pattern type appeared in the questionnaires

Pattern type	N	Mean	SD
Repetition	195	3.57	1.23
Reflection	249	4.04	1.71
Repetition and Reflection	135	4.67	4.49
Rotation	61	3.95	1.31
With noise	381	2.37	1.34

3.3.2 *Complex and simple patterns*

Simple patterns, those that were based upon 2x2 square elements were compared with those for complex elements, those based upon single squares. There was a highly significant difference between the median ranks for simple and complex patterns, $U = 104164$, $N_1 = 616$, $N_2 = 404$, $p<0.001$. Complex patterns, those constructed using smaller elements, on average received higher rankings than the simple patterns, those that were constructed using 2x2 square elements (Figure 3.6).

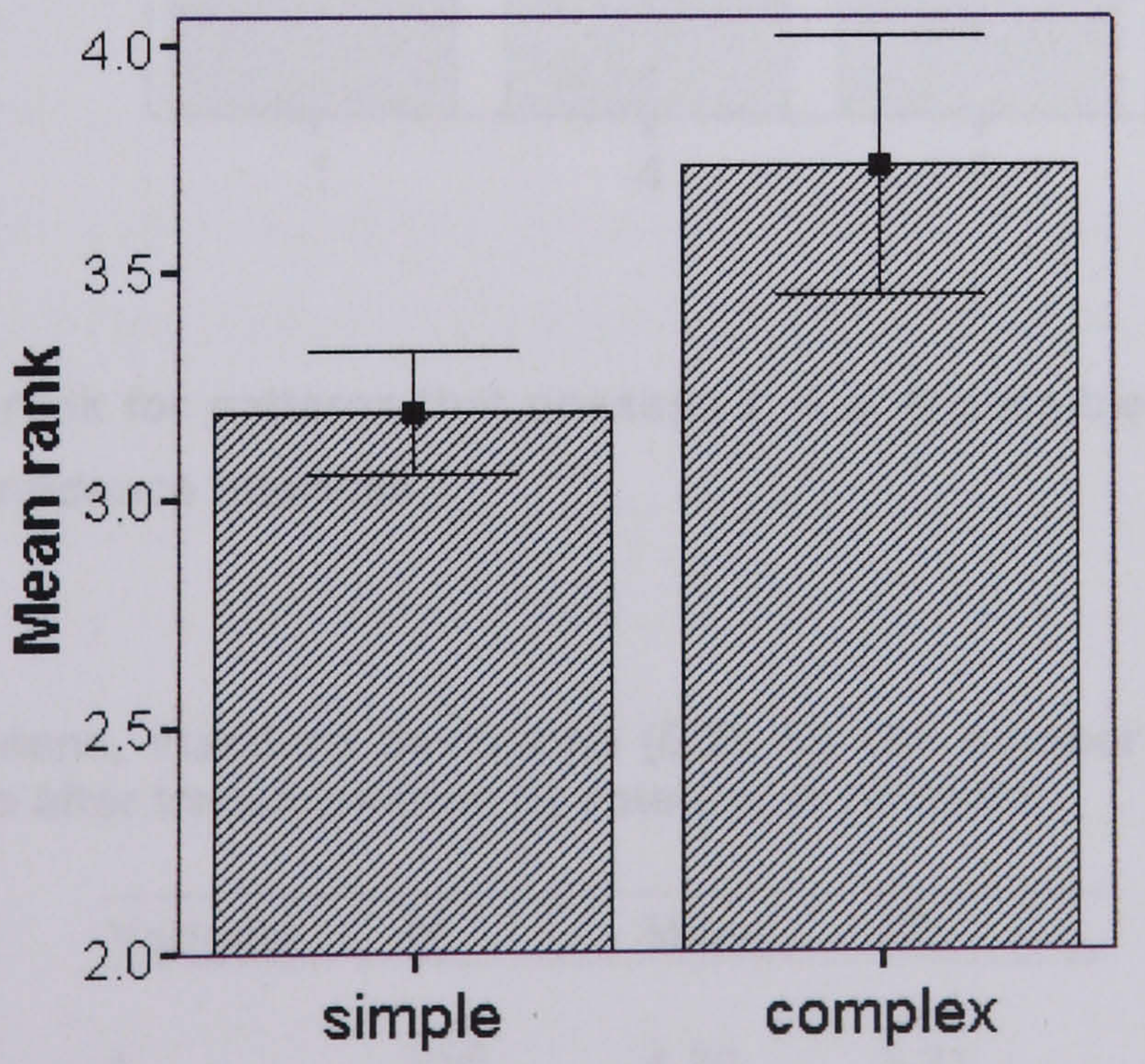


Figure 3.6: Mean rank for simple (M = 3.19, SD = 1.68) and complex (M = 3.73, SD = 2.92) patterns.

3.3.3 *Figural goodness*

Patterns that have only one variation were ranked significantly higher than those that contain more than one variation (see Figure 3.7). A Kruskal-Wallace test showed that there are significant differences between the 1 variant, 4 variant and 8 variant patterns, $\chi^2 = 262.395$, df = 2, $p < 0.001$. This is in accord with models of figural goodness. The means and standard deviations for each of the different variants are shown in Table 3.2.

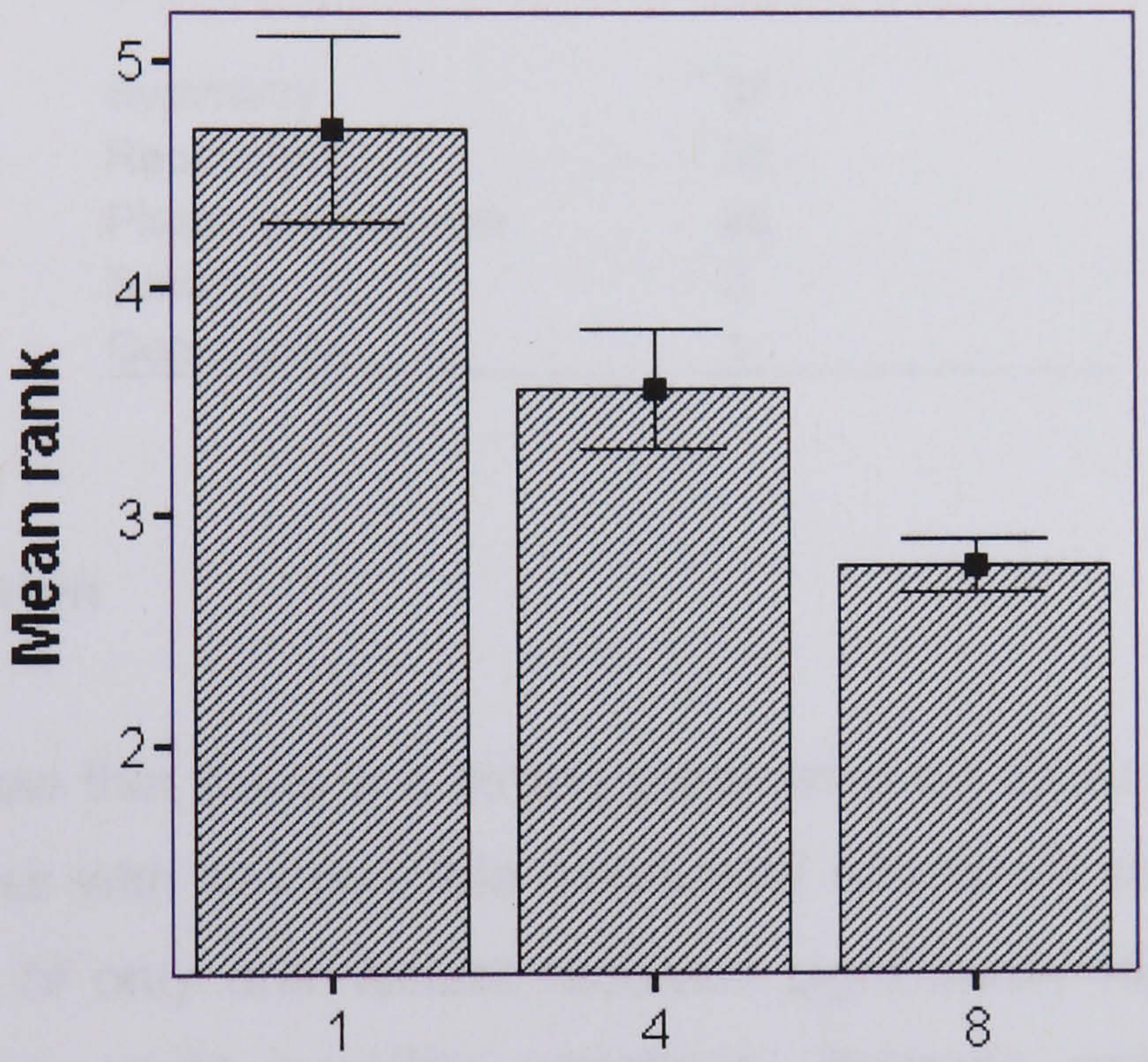


Figure 3.7: Mean rank for patterns that possess 1, 4 or 8 possible variants. Error bars represent 95% confidence intervals.

Table 3.2: The means, standard deviations (SD), for the number of variations that a pattern possesses after transformation by rotation or reflection.

Variants	N	Mean	SD
1	258	4.70	3.31
4	187	3.56	1.81
8	575	2.77	1.42

3.3.4 *Participant definitions*

The results regarding which of the keywords are most suitable in describing a pattern are shown below in Table 3.3. These results suggest that repetition and symmetry are the two most frequently stated definitions. However, reflection was not selected as a keyword alone unlike repetition. Complexity and novelty were rated as not being important factors in defining patterns and constituted less than 5% of the selected words.

Table 3.3: Percentage breakdown of terms that define a pattern

Definition	Percentage
Symmetry	37
Repetition	35
Pleasing to the eye	25
Novelty	2
Complexity	1

3.4 Discussion

The results show that there is a strong preference for patterns that show high figural goodness with few possible (rotational/ reflection) variations. Patterns that consisted of only one variant received significantly higher ratings than those that have eight possible variations. Patterns containing reflective symmetry were ranked higher than repetitive patterns. However, reflection in isolation was not selected as a keyword, while repetition appeared 35% of the time in public definition of what is a pattern. The preference for reflected patterns was in accord with previous studies into reflective symmetry versus repetition (Baylis & Driver, 1994). Overall the complex patterns were rated more generously than simple patterns. However, complexity was not a word that was readily associated with patterns within this sample. This could suggest that a perception for increased repetition of elements and a differentiation between what is considered an object and a pattern. However, within the definition provided by participants, 'pleasing to the eye' constituted

25% of the defining words and phrases. This emphasises the aesthetic nature of pattern perception.

A pattern therefore is a series of elements arranged by repeated symmetry and exhibiting high figural goodness as well as a degree of complexity. The important distinction lies in where to draw the boundary between the definitions of an object and a pattern. The questionnaires are highly reliant on personal opinion of what constitutes a pattern and as such might simply reflect a participant's aesthetic biases. However these aesthetic biases are themselves an important factor as 'pleasing to the eye' was considered a defining factor and arguably the basis for theories of figural goodness and the Gestalt laws are aesthetically based approaches to object and pattern perception. One factor that was not fully accounted for by this pilot study was the axis of reflection, however this is addressed within the main study.

These definitions are particularly relevant to how participants interpret instructions and experiments that utilise patterned abstract stimuli. The participant comes complete with a set of preconception regarding what can be considered a pattern. Their biases are demonstrated in preferences for minimal uncertainty, i.e. a low number of possible image variations, and aesthetic qualities.

In relation to social stimuli, the human face possesses many of the above criteria. The face possesses repeated elements such as eyes, ears, nostrils and teeth, and elements reflected across a central axis such as eyes, teeth, mouth, nose, and ears. It is clear that these features are not easy to classify into one mutually exclusive category of symmetry, however this concurs with the criteria specified by the public in the survey. Much of the current research into face perception cites the importance of both configuration and symmetry in the perceived aesthetics of a face (Jones et al., 2004; Jones et al., 2003; Jones & Hill, 1993; Perrett et al., 1999). Therefore symmetry appears to be a useful means for assessing both abstract and social visual patterns.

3.5 Defining facial patterns

One of the recurring themes within studies of face perception is that of the relative importance of featural or component properties (Carey & Diamond, 1977) and the spatial interrelationship of features or configural properties of a face (Bruce, 1988). The relative importance of each of these properties, configural and component, can be reduced to one basic question, what is it that makes a face face-like? The Oxford English Reference Dictionary 2nd edition (1996) provides two contrasting descriptions of what a face is. Below are the two definitions.

1) The front of the head from forehead to the chin.
2) The expression of the facial features.

These two definitions suggest the importance of the topographical location of the face and of the individual features in defining a face. The face represents probably the most important social stimulus for human social groups. The face can be used not only for detecting sensory information but also for communicating intentions and emotions. However, humans are capable of attributing face-like properties to images that are not true representations of real faces, for example cartoons.

In experiments that involved participants viewing the movement of animated abstract shapes, i.e. squares and triangles, there was a tendency for the viewers to anthropomorphise the movement of the shapes attributing human intentions and emotions to the stimuli (Heider & Simmel, 1944). Martin and Weisberg (2003) extended the work of Heider and Simmel using fMRI technology. Participants were shown short vignettes with moving abstract shapes that appear to interact. When watching a vignette containing interaction between the abstract shapes the posterior temporal cortex areas of the brain were activated particularly those areas associated with face perception, biological movement and the emotional brain areas such as the amygdala. These examples highlight that the component properties, i.e. the facial features, of a stimulus or face are not necessarily those that make a stimulus an intentional agent. Instead other factors including they way object moves provide the intentionality. Similarly with face perception it is not necessarily the featural components that are the most important factor in face identification but the spatial configuration and the way these features move within the face.

The face is a largely bisymmetrical feature and in a schematised form would represent an image that would possess four variations when examined in terms of figural goodness (Figure 3.8). Evidence from face inversion studies suggests that configural and feature changes to inverted faces are more difficult to detect than in upright faces (Thompson, 1980; Murray, Yong, & Rhodes, 2000). Therefore in terms of figural goodness, the visual system would appear to be only sensitive to three of the possible variants, i.e. the upright face and the two rotated by 90° conditions (see Figure 3.8). This would suggest that the pattern of the face is highly important in the definition of what is regarded as being face-like and that images that contain the correct orientation and spatial distribution of internal elements will be conceived as being more face-like.

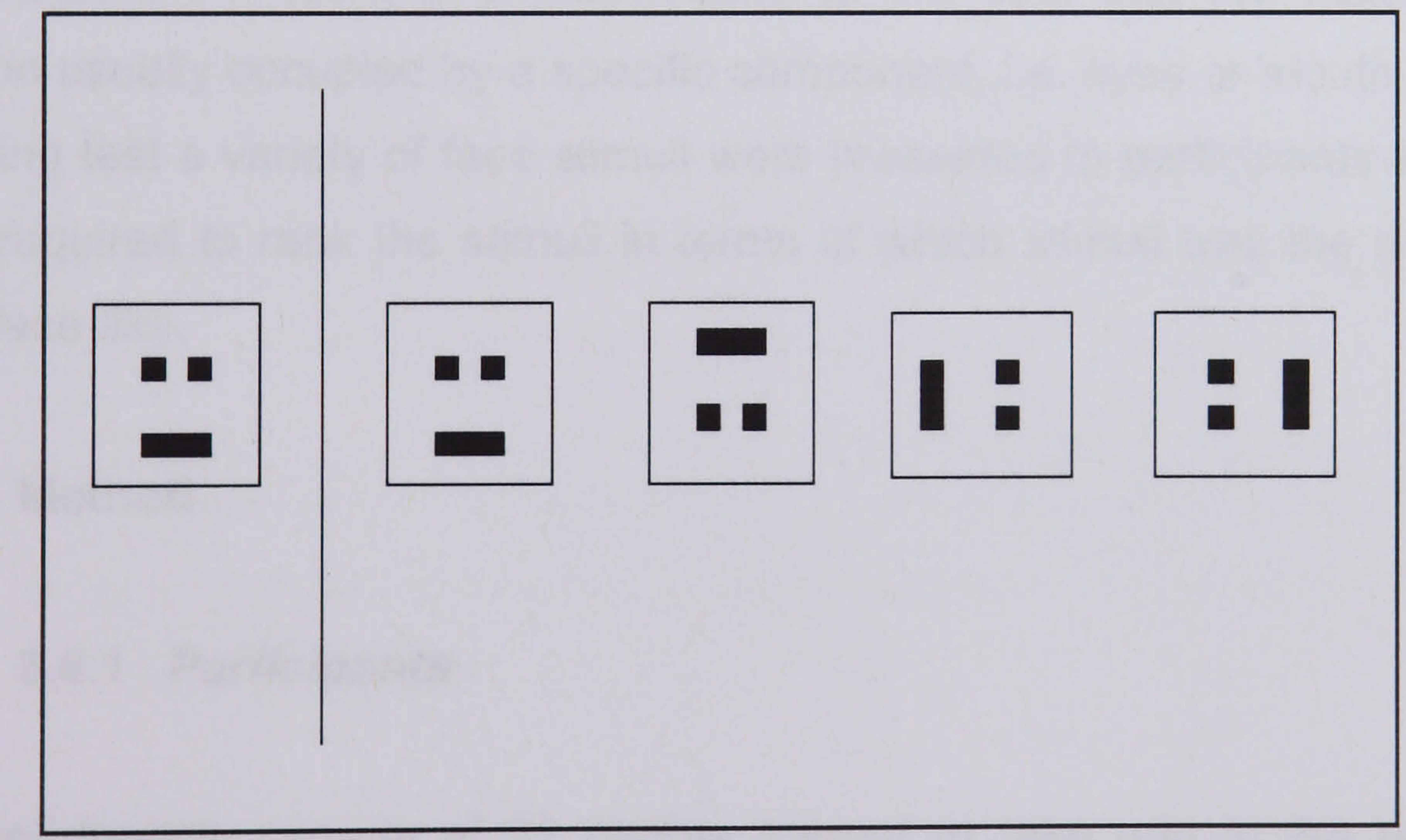


Figure 3.8: The 4 possible variants for a schematised bisymmetrical face stimulus

In tests on other visual biological stimuli, crustaceans and insects, it has been shown that there is still sensitivity to the orientation of symmetry even when the image is converted into a dot pattern (Evans, Wenderoth & Cheng, 2000). The accuracy of responses to changes in the symmetry of the dot patterns generated from natural stimuli was reduced compared to that of the images for the original natural stimuli. However, despite a reduction in overall accuracy the same effects in terms of reduced accuracy for reflection across the horizontal as compared to the vertical axis were observed within the dot patterns. This suggests that the reflective symmetry properties of a stimulus can be examined and interpreted independently of the fine detail, i.e. colour and texture, and the individual component properties, i.e. features.

If the components of a face, i.e. the mouth and the eyes are converted to points or dots, would the stimulus still be perceived as a face or even more face-like when compared to a face with normal features that are not configured in a bisymmetrical way? Arguably dots presented within the facial configuration could represent any one of the features and not necessarily the ones that are usually present within a particular spatial arrangement. However, in accord with the idea of simplicity and information redundancy (Chater, 2000; Sharroo & Leeuwenberg, 2000), there is a likelihood that the participants will go for the easiest, most commonly experienced explanation and attribute the featural characteristics to the dots that are located in a position usually occupied by a specific component, i.e. eyes or mouth. For the following test a variety of face stimuli were presented to participants and they were required to rank the stimuli in terms of which stimuli was the most and least face-like.

3.6 Method

3.6.1 *Participants*

An opportunistic sample of 92 people agreed to take part in the test. The sample was obtained from the University of Gloucestershire Campus. Participation in the experiment was entirely voluntary and all responses were anonymous.

3.6.2 *Apparatus and Materials*

A simple questionnaire was designed that contained four different possible face stimuli (Figure 3.9). This consisted of two stimuli that were based upon a photo fit image created using FACES software (InterQuest Inc., 1998). One of these faces contained the features in the normal configuration and therefore contained both component and configural information. The second face contained the component information but the features were placed out of context so as to disrupt the spatial and therefore configural relationships between them. The second type of stimuli was based on abstract oval shapes containing four dots. These dots were either placed in a configuration similar to the normal face or a configuration similar to the face with jumbled features. In the abstract oval condition the configural information was retained while the featural information was lost.

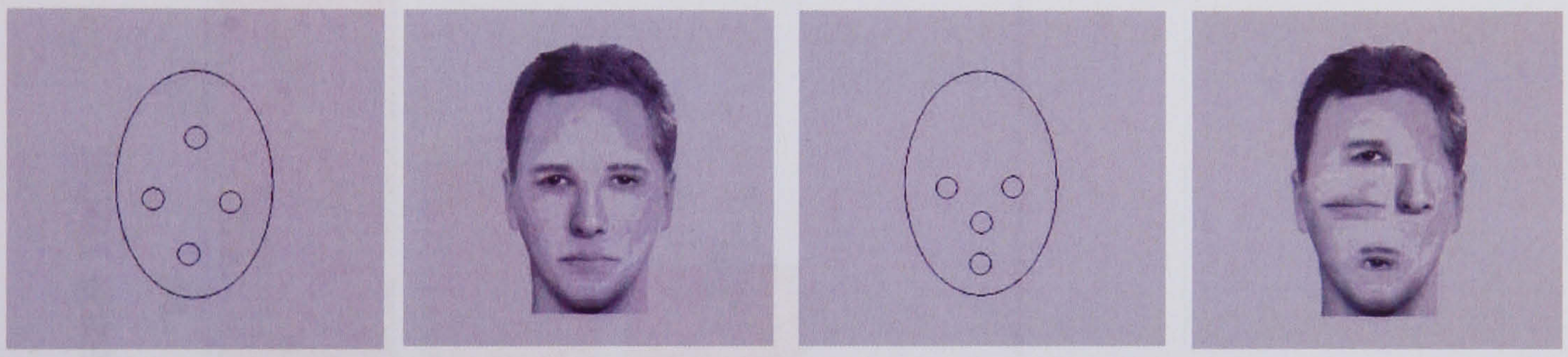


Figure 3.9: The test stimuli used in the questionnaire, from left to right: for dots arranged in a diamond shape within an oval, a normal face, 4 dots arranged in same position as in the normal face stimulus and a normal face with jumbled features.

The questionnaire asked the participants to rate the faces in order of which face they perceived to be the most face-like, where 4 = the most face-like and 1 =the least face-like image.

3.6.3 *Procedure*

Participants were requested to rate the four images in order of which image they believed to be most face like. The experiment took approximately 2 minutes to complete. All responses were kept anonymous.

3.7 Results

All of the participants identified the normal face with normal features and configuration as being the most face like (Table 3.4). There was a highly significant difference between the median ranks for the face with jumbled features and the abstract image that comprised of dots in a normal face configuration, $U = 2202.5$, $N_1 = 92$, $N_2 = 92$, $p < 0.001$. This suggests that the dot image with normal configuration was generally perceived as being more face-like than the face with jumbled features (Figure 3.10). The abstract image with the dots arranged in a diamond shape, i.e. similar configuration to the jumbled face, was the face most frequently considered as the least face-like of the 4 stimuli.

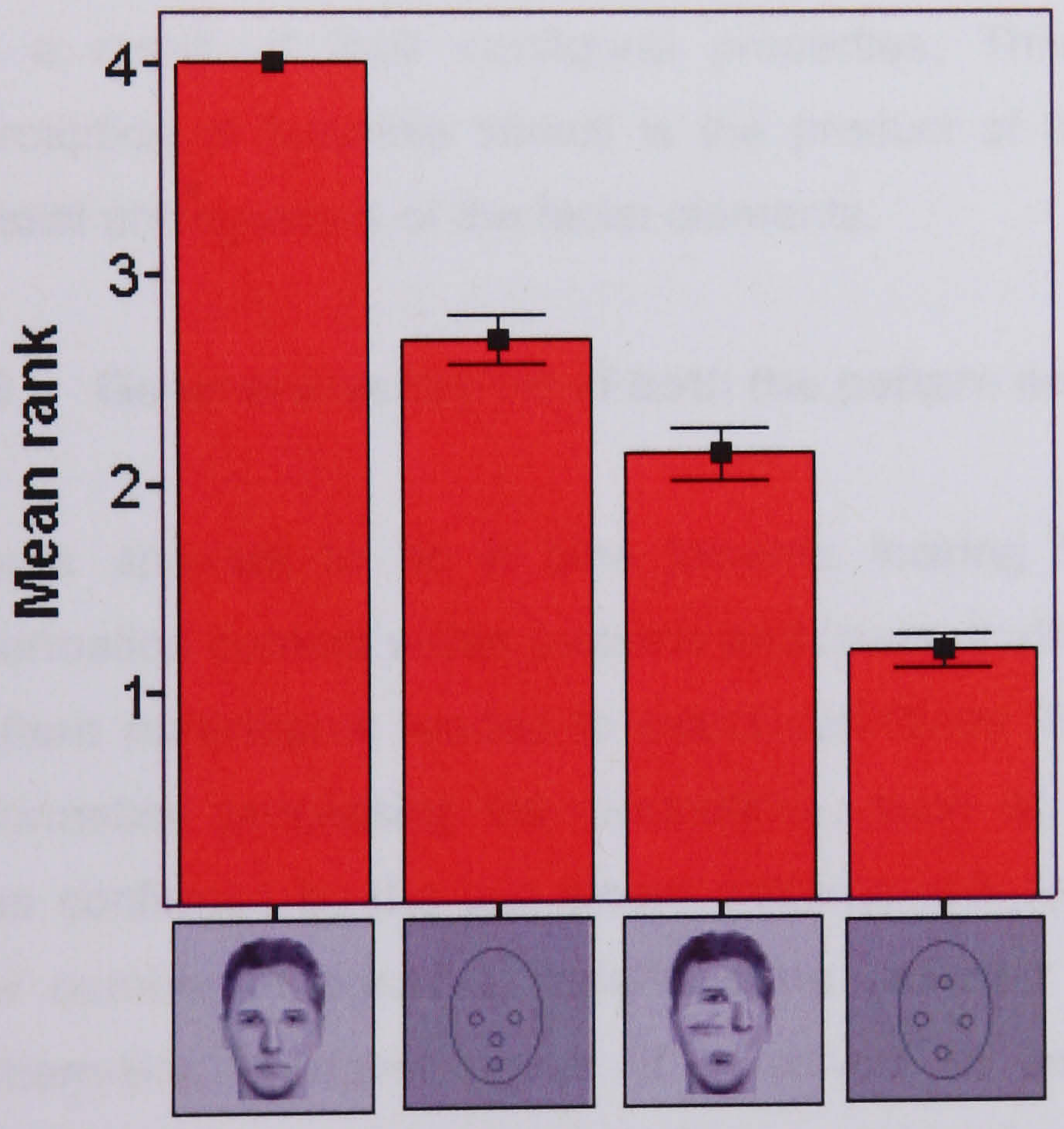


Figure 3.10: The Mean ranks for the different face stimuli: 1 = least face-like and 4 = most face-like.

Table 3.4: Means and standard deviations (SD) for the different types of face stimuli.

Face	N	Mean	SD
Normal face	92	4.00	0.00
Dots in normal configuration	92	2.68	0.57
Face with jumbled features	92	2.13	0.60
Dots in jumbled configuration	92	1.18	0.42

3.8 Discussion

The face questionnaire illustrates that in general there is a bias to attributing face-like qualities to stimuli that are configured in a specific spatial arrangement. This appears to be more important than the constituent components. The dots in the abstract stimuli do not actually represent a specific feature, however, the participants attribute those features to the dots as a result of their configural properties. This could suggest that the perception of face-like stimuli is the product of the bilateral symmetry and spatial arrangement of the facial elements.

3.9 General discussion of both the pattern and face definitions

There appears to be a bias towards looking for ways of reducing the information content within patterns and faces. In describing what constitutes a pattern participants tended to select definitions that confer an advantage in information processing via redundancy, such as increased symmetry. This was confirmed by the test where patterns with high figural goodness and a low number of possible variants were selected more frequently as being pattern-like. However, faces, if perceived as being a pattern, possess 4 possible variants in a schematic form and therefore are arguably not the most pattern-like stimuli according to this definition. This number of variants though would rarely be experienced as faces are infrequently encountered in an inverted position. Therefore in terms of the viewer's usual body orientation, faces are usually with only 3 possible variations, upright or tilted to either side.

The definition of what constitutes a face is very sensitive to the spatial arrangements of the internal components. Therefore there is a specific pattern and symmetry that is perceived as being face-like. The features of the face were not perceived as not being as important in defining what is face-like. The face appears to have been defined primarily at a global level in terms of how the featural components are positioned within the face.

This pilot study highlights several key areas for investigation in the early visual processing of patterns. These include the role of symmetry type in the saliency of a patterns, this could be reflected in greater saliency for different symmetry types at different levels of visual perception. This also highlights the possible top-down effects as the pilot studies provide information on the preconceptions of the participants towards particular symmetry types. As there is a preference for patterns with greater symmetry, reduced number of possible variations these could affect the accuracy of pattern detection at post V1 stages of visual processing. Similarly with the face stimuli as there is a predisposition towards the spatial arrangement of the components within the face then deviations from this might be detected more rapidly than changes to individual features.

Chapter 4: Backward masking and general methodology

One of the main aims of this investigation was to examine the earliest phases of visual information processing in regard to the perception of "patterns". To this end the methods used were designed to allow these early intervals to be explored. In order to provide a scale by which processing time can be measured, a methodology that interrupts the processing of the target stimuli at a specific point was required. One of the most widely used and effective means of doing this is the procedure of backward visual masking. The disruption of perceptual continuity provided by backward visual masking could result in a lack of awareness of the target stimulus by the participant. Such masking methodologies provide a useful tool in examining how different stimuli are perceived and how these stimuli can affect perception at preconscious stages of visual processing. However, the salience of different images and the rate at which these images are processed might alter the effect of the masking image. In the following sections the different variations in masking methodology are described and the choice of target stimulus, mask and methods of interpretation of the results are discussed.

4.1 Masking procedures

One technique that is frequently adopted to understand the nature of the time course of visual processing is that of visual masking. There are two types of masking, forward masking and backward masking. The difference between the two types depends on whether the masking stimulus is presented before (forward masking) or after (backward masking) the target is displayed (Bachmann, 1994; Breitmeyer 1984). In investigating the time course of visual perception, backward visual masking allows for the study of perception post stimulus offset and is therefore used as the principal method in this thesis. In backward masking a briefly presented target stimulus is shown to a participant and after a temporal delay followed by a masking image. This masking image disrupts the further processing of the target stimulus. However, the choice of mask can alter the way in which a target is masked and as such backward visual masking can cover a variety of different masking procedures including masking by brightness (Georgeson & Georgeson, 1987; Sperling, 1960b; Turvey, 1973), pattern masking (Enns & Di Lollo, 2000; Turvey, 1973) and metacontrast masking (Klotz & Neumann, 1999; Lefton, 1973). The choice of mask is discussed further in section 4.

Masking by brightness involves the presentation of a flash of light post target presentation that disrupts the further processing of the target stimulus (Sperling, 1960). Metacontrast masking is so named as the masking stimulus closely fits the contours of the stimulus but does not overlap (Alpern, 1953; Breitmeyer & Ogmen, 2000; Lefton, 1973; Werner, 1935). A simple example of this would be to present the negative of a stimulus. In pattern masking the masking stimulus overlaps the contour of the target stimulus and does not necessarily trace the target stimulus in any form (Turvey, 1973). The advantage of pattern masking is that one mask can be used for several stimuli, as opposed to the specificity of metacontrast masking. In this study pattern masking is used due to its flexibility with a large range of differing target stimuli. Therefore only one type of mask is required as opposed to an individual mask for each individual target stimulus.

Backward masking procedures take advantage of the way in which sensory information persists within the visual system for a period of time after stimulation. It has been suggested that there is an iconic memory store that holds visual information for a few milliseconds after the onset of a visual image (Sperling 1960a; 1963). Iconic memory is a rapidly fading, high capacity visual memory that is available for a short period of time post stimulus presentation. Although in recent years the existence of and usefulness of studies into a high-resolution iconic memory have been questioned (Haber, 1983; Sakitt, 1976), early studies into iconic memory provide a useful demonstration of the efficiency of masking procedures.

In a series of classic experiments examining iconic memory, Sperling (1960a), examined the amount of information that can be recalled in a brief presentation. Sperling presented subjects with 3 rows of 4 letters for a duration of 50ms and asked the participants to recall as many of the letters as possible. In general participants were only able to recall 4 or 5 of the letters presented to them despite being aware that there were more letters. Sperling then asked the participants to recall only one of the rows of letters. A high, medium or low tone was used to signal which of the 3 rows the participant should recall. The cueing signal was presented either 100ms prior to the target stimulus onset, or up to 1-second post stimulus offset. When the tones were presented either immediately before or immediately after the offset of the target stimulus, approximately 9 of the 12 letters could be recalled via the partial reports. However, after 300ms this dropped to approximately 6 letters and then after 500ms post stimulus offset the number of letters that could be recalled again was reduced to 4 or 5 letters. Sperling suggested that the complete grid of letters was available as a high-resolution icon for the participants to recall information from for approximately 150ms post stimulus offset.

In a further experiment Sperling (1960a) altered the brightness of the blank field occurring prior to the target letters. Under these conditions Sperling noted that the iconic memory appeared to persist for longer durations, however, if a brighter flash of light followed the target stimulus then the participant's performance was impaired. The bright flash acted as a masking stimulus disrupting the visual processing of the information contained in the target stimulus. Turvey (1973) conducted a series of experiments to investigate where iconic memory storage could possibly be occurring.

Following on from the work of Sperling (1960a), Turvey used a combination of different masking methodologies, brightness masking and pattern masking. The brightness masking involved the use of a flash of light post target presentation, while the pattern masking involved the use of a random masking image constructed from structural elements similar to the target letters. The brightness masking was shown to only disrupt visual processing if presented to the same eyes as the target. This suggests that the mask is acting at an early retinal level before prior to the point where the information from the two eyes is combined. The disruptive effect of the brightness mask was also shown to be a joint multiplicative function of its brightness and it's duration.

However, for pattern masking the intensity of the stimulus was not an important feature, instead the interval between the offset of the target and the onset of the mask was the crucial factor in masking. Pattern masking was also independent in terms of which eye the mask and target were presented. Turvey (1973) suggested that this evidence showed that there was a multistage iconic memory, one that is relatively peripheral as illustrated by the brightness masking and one that occurs at a stage post V1 as illustrated by the pattern masking. In terms of this thesis the work of both Turvey (1973) and Sperling (1960b) highlight two important methods of masking and the subsequent effects they have on memory recall of a briefly presented stimulus.

The experiments of Sperling (1960a; 1960b) and Turvey (1973) both utilised letters and were experiments that did not reflect the way in which images are perceived naturally. As criticised by Haber (1983), investigations into iconic memory can be considered as only useful in examining how an individual would read in a lightening storm, and confer little ecological validity. However, as illustrated by the experiments of Sperling and Turvey they provide a useful technique in the interruption of the normal visual process and as suggested by Julesz (1983) different types of stimulus have different 'iconic' salience.

According to Scheerer (1973), backward masking succeeds in obscuring the perception of the target image by one of two ways. These are integration effects and interruption effects. Integration occurs if the target and mask are combined into a unitary percept. The integration of the image is suggested as occurring at an early stage of visual processing either in the peripheral visual areas, i.e. retinal vision, or in early V1. The properties of the mask result in a degradation of the target. Integration effects are maximal when the mask is presented at very brief stimulus onset asynchronies, i.e. when the target and mask are presented at approximately the same time (Breitmeyer, 1984; Turvey, 1973). The processes suggested by integration effects share common characteristics to extra-retinal processes used during saccadic suppression that integrate and buffer the visual scene during rapid eye movements (Diamond, Ross & Morrone, 2000; Thilo et al., 2004).

Interruption effects occur when the processing of the target is disrupted by the arrival of the masking image. The mask then takes over the processing mechanisms that are required by both stimuli. The mask therefore prevents information from the target image being fully processed within the extra-striate visual areas. Masks that are associated with interruption effects include pattern masks, where the mask spatially overlaps the target and meta-contrast masks where the contours of the mask follow but do not overlap the contours of the target image. Interruption effects are maximal after initial intervals but can occur at later SOAs depending on the energy and spatial frequency of the masking stimulus. The properties of the choice of mask are discussed in section 4.5. Despite the clear distinction between interruption and integration effects they are not necessarily mutually exclusive and are dependent on the choice of target stimulus and masking stimulus (see section 4.3 for more detail).

4.2 Neuronal evidence for backward visual masking

In recent years there have been many differing explanations of what could be occurring within the early visual system during masking experiments (Breitmeyer & Ogmen, 2002). These explanations include the use of neural network models, attentional models, re-entrant processing and perceptual retouch (Breitmeyer & Ogmen, 2000; Enns & Di Lollo, 2000; Ogmen, Breitmeyer & Melvin, 2003; Breitmeyer, 1984). However, for the purpose of this thesis the main focus of attention is on whether the use of a masking methodology actually limits the perceptual processing of the target stimulus or whether observed masking effects are the result of the decay of a subsequent iconic memory. The evidence for how visual masking methodologies disrupt the visual processing of a target stimulus have so far been based on behavioural responses to experiments, however there is a growing volume of evidence obtained by studies into neuronal activity that provide evidence as to how masking functions at a cortical level (Kovacs, Vogels & Orban, 1995; Macknik & Haglund, 1999; Rolls & Tovee, 1994).

Rolls and Tovee (1994) examined the effect of visual masking on the firing rate of single neurons in the macaque cortex. In their experiments they presented pictures of faces that stimulated a specific neuron in the superior temporal sulcus of the macaque cortex and measured the rate of firing under different presentation conditions. A fixation point was presented for 400ms followed by a blank screen for 100ms. This was followed by the presentation of the visual stimulus, a picture of a face, for 16ms. The SOAs between the target stimuli and the masking stimuli were, 20, 40, 60, 100 or 1000ms. They noted that neurons fired for approximately 200 - 300ms after a face was presented without the effect of any interfering stimuli, this is far longer than the actual presentation of 16ms. They suggest that this could illustrate a type of visual short-term memory, similar to that of the iconic memory suggested by Turvey's (1973) pattern masking experiment. If the mask presented was a stimulus that did not fire the neuron, in this case a face that did not stimulate the particular neuron or a non-face pattern, then the length of time the neurons fired post target presentation was reduced in line with a reduction in the SOA.

Kovacs et al. (1995) showed that the same effect could be noted for the backward masking of patterns. In this version the target stimuli were outlines of shapes and the masking stimulus a combination of all the target shapes. Kovacs et al. (1995) examined a set of neurons in the macaque inferior temporal cortex and noted that the masking stimuli had the effect of shortening the response time of the neurons. However the experimenters could not be totally sure if the macaque had actually perceived the target stimulus despite the reduction in neuronal firing. Therefore they also conducted non-invasive psychophysical experiments on two human subjects where over 400 trials the human participants had to identify whether or not a pattern was presented. The results showed a reduction in accuracy with a reduction in SOA. This suggested that the macaques did not perceive the target stimulus at the shorter SOAs. Therefore Kovacs et al. (1995) concluded that the masking stimulus had the effect of interrupting the neuronal firing process and consequently interfered with the perception and identification of the target stimulus. The experiments of Kovacs et al., (1995) and Rolls and Tovee (1994) provide neuronal evidence for interruption effects for both abstract stimuli, i.e. shape outlines, and more ecologically valid stimuli, i.e. faces. This suggests that although as suggested by Julesz (1983) different stimuli may be held for different periods of time within the visual processing system, pattern masking can still provide a useful methodology for disrupting the further processing of specific visual stimuli.

The evidence provided so far suggests that backward visual masking limits the information provided to the non-striate visual areas of the superior temporal sulcus and the inferior temporal cortex. However the studies of Rolls and Tovee (1994) and Kovacs et al., (1995) do not suggest whether the mask is interrupting the target at the shorter SOAs or whether the target is being integrated with the masking stimulus. Consequently, Macknik and Haglund (1999) investigated the effect of backward visual masking on area VI of the macaque visual cortex. The masking stimulus consisted of counter-phase flickering bars that were used to mask a single bar stimulus. When the target was presented alone it generated a strip of activity on the surface of the cortex, however when the mask was presented alone two strips of activity separated by an area of lesser activity were generated. This suggests that different populations of neurons were firing for the target and masking stimuli within area V1. During the actual masking trials, when the target bar was perceived as being invisible by the macaque, Macknik and Haglund (1999) observed that only the areas of the cortex that were associated with the detection of the masking stimulus were active. This evidence suggests that the processing of the target stimulus was interrupted in the primary visual areas and that the masking stimulus subsequently dominated the later stages of visual processing.

The three studies outlined (Rolls & Tovee, 1994; Kovacs et al., 1995; Macknik & Haglund, 1999) indicate that despite the interrupting effect of the masking stimulus the neurones and brain areas that are stimulated by the presence of the target are still activated, albeit for a reduced period of time, during masking. However, at the lower SOAs the reduced neuronal activity is below a threshold level and the participant does not actively perceive the target stimulus. This suggests that the mask is interrupting the continued processing of the target and its availability to the conscious mind and short-term visual memory (Baddeley, 1992; Baddeley & Andrade, 2000).

4.3 Mechanisms of interruption: Feed forward inhibition versus re-entrant processing

There are two main models used to explain the disruptive effects of backward visual masking, feed-forward inhibitory models and re-entrant processing models. Evidence for the feed forward mechanism first came from Spencer and Shuntich (1970), who noted that the effect of backward masking is strongest at SOAs of less than 100ms. The second stimulus therefore catches up and interrupts the initial signal before it is made available to the conscious brain. Further evidence for an interruption of processing at a pre-categorisation level has been put forward (Brehaut, Enns & Di Lollo, 1999; Kammer, Scharnowski & Herzog, 2003; Kovacs et al., 1995). The second model is one where there is interruption of re-entrant or recurrent processing (Enns & Di Lollo, 2000). In this model, information flows within the visual processing stream from low (primary visual areas) to high levels (non-striate cortex), and then back to the low levels. It is only after a series of recurrent processes that the stimulus is made available to the conscious brain. The interruption occurs as the masking signal blocks the target signal during the early stages of re-entrant processing. Therefore the target signal cannot be processed further or actively attended due to the presence of the second signal. This interruption of re-entrant processing fits with theories of attention that suggest a necessity for active interaction between the individual and stimuli (O'Regan & Noe, 2000; Gibson, 1979).

However, it has been shown that backward visual pattern masking does not prevent stimulation of the higher visual areas, the extra-striate and non-striate areas. This suggests that the feed forward idea is unlikely as the second stimulus should have interrupted or inhibited the flow of information to these areas (Rolls & Tovee, 1994). In fact Macknik and Livingstone (1998) showed that pattern masking has to occur sometime around or after V1. In a study of 25 human participants they presented the target to stimulus to one eye and the mask to the other eye, and still managed to obtain a masking effect suggesting that masking was not occurring at a retinal or pre-striate phase of processing. However, as previously mentioned the type of mask, i.e. pattern, brightness or meta-contrast, can influence at which stage the masking effect occurs.

However the problem of why the stimulus is not recognised despite evidence of neuronal firing could be answered in terms of re-entrant signal processing. In this theory (Di Lollo, Enns & Rensink, 2002; Di Lollo, Enns & Rensink, 2000), the processing of visual stimuli is not considered as a unidirectional process, instead there is a bi-directional process occurring between the higher processing levels and lower processing levels. These processes occur until the identity of the object has been fully reconciled. The masking stimulus interrupts the low level processes and therefore disrupts the higher level processes. This would mean that the masking stimulus replaces the target stimulus in the low level processes breaking the bi-directional flow of information and preventing the ongoing matching of high level and low level processes (Di Lollo, Enns & Rensink, 2000). This bi-directional processing theory assumes that the brain is modular in the manner in which it processes visual stimuli. Therefore at the higher level there is iterative comparison of visual codes while at the lower level the re-presentation of the initial target stimulus is maintained until such time as it is interrupted. Hupe et al. (1998) showed that when processing visual stimuli a large range of neurons are activated in several areas. They identified feed forward connections that transmit information from the lower areas (V1 and V2) to higher processing areas. They then identified a dense web of feedback connections that they propose amplify and focus neurons in lower order areas and are important in the differentiation of figure from ground. The feedback connections therefore are necessary for the integration of information concerning different parts of the visual field.

4.4 The choice of stimuli: abstract or ecological?

In the previous section it has been established that masking does have an effect and can be utilised to disrupt the processing of different stimuli at different temporal intervals. However, before deciding on an appropriate method of masking the choice of target stimulus has to be considered. In this thesis the main focus was on the early visual perception of patterns both in abstract and ecologically valid stimuli. The majority of studies that utilise backward masking methodologies use abstract stimuli, i.e. not natural scenes or elements of natural scenes. Table 4.1 provides a summary of the different stimuli that have been used in visual masking procedures. The benefits of using an abstract stimulus are that the properties of the target stimulus can be more effectively tailored to answer a specific question about visual processing. Stimuli such as bars, lines, checkerboards and shape outlines can be easily adjusted to test one variable at a time, as the basic properties of the stimuli can be simply defined and are not loaded with semantic meaning. For example abstract images are particularly useful in examining the time course and neural correlates of visual perception (Francis, 2003; Kovacs et al., 1995; Ogmen et al., 2003; Rolls & Tovee, 1994; Rolls, Tovee & Panzeri, 1999), discrimination of orientation effects in early vision (Vidnyansky et al., 2001) and investigating visual awareness deficits as the result of medical conditions such as depression or schizophrenia (MacQueen et al., 2001; Green et al., 2003). Abstract target stimuli are also easier to mask as variables such as contrast, luminance and spatial frequency can be controlled and accounted for and the choice of mask tailored appropriately (see section). Therefore, the use of abstract stimuli is important in discriminating between possible differences in the visual processing of different pattern types and is used within this thesis.

Despite conferring high internal validity, abstract stimuli do not necessarily reflect the true nature of visual perception. Normal vision does not consist of abruptly presented abstract shapes but comprises of an apparently fluid flow of complex natural images. Visual masking methodologies would confer greater ecological validity if the experiments were presented within a more naturalistic context. For example Carroll and Bever (1976) examined the effect of recalling a probe within a film sequence. The probe sequence was a 375ms excerpt taken from the main film. The main films consisted of people in conversation, people walking around, or traffic. Carroll and Bever (1976) found that after an edit, i.e. a change in shot such as a change in distance or scene, the recognition of the probe stimulus was impaired. However when the probe was shown after the cut in the second sequence then recall time was significantly improved. They concluded that the switch in shot could have been acting as a masking stimulus disrupting visual processing when there was both a cut in a scene and a change in action. In many ways this experiment illustrates a natural masking paradigm as the test information is presented in a naturalistic manner and represents natural scenes that could be encountered within daily life. However, the presentation of a masking experiment within the confines of a cinematic environment are not practical and difficult to control in terms of technical equipment, presentation rate and timing accuracy.

Although it is difficult to examine the time course of visual perception utilising a truly naturalistic and ecologically valid method, ecologically valid target stimuli can still be used to great effect to examine a variety of different problems. For example the visual masking of ecologically valid stimuli has been used to examine the unconscious perception of emotional facial stimuli (Morris, Öhman & Dolan, 1998), hemispheric differences in the processing of faces and words (Heider & Groner, 1997) and the effects of briefly presented alcoholic stimuli on the heart rate of alcoholics (Ingjaldsson et al., 2003). Such ecologically valid stimuli allow for the investigation and interruption of visual processes pre- and post-categorisation. Similarly when investigating pattern perception it would be interesting to investigate whether there are any top-down influences on visual perception imposed on the pattern interpretation. Therefore, the use of a commonly experienced ecologically valid stimulus such as the human face provides a stimulus choice that contains a variety of patterned elements and conveys a wealth of social information.

Table 4.1: Stimuli types and the backward visual masking studies that have used them.

Type of stimuli	**Study**
Letters and digits	Enns (2004), Sanborn et al. (2004), Kawahara et al. (2003), MacQueen et al. (2001), Horowitz (1998), Heider & Groner (1997), Ward & Duncan (1996), Wolford et al. (1998), Hellige et al (1979), Spencer & Shuntich (1970), Dember & Purcell (1967).
Lines and bars	Deary et al. (2004), Kammer et al. (2003), Francis (2003), Abrams & Law (2002), Vidnyansky et al. (2001), Verney et al. (2001), Macknik & Haglund (1999), Macknik & Livingstone (1998)
Shape outlines	Ogmen et al. (2003), Green et al. (2003), Rauschenberger & Yantis (2001), Enns & Di Lollo (2000), Kovacs et al. (1995),
Natural stimuli (e.g. faces, objects and natural scenes)	Ingjaldsson et al. (2003), Rolls et al. (1999), Morris, Öhman & Dolan (1998), Hollingworth & Henderson (1998), Heider & Groner (1997), Harmon & Julesz (1973).

Both abstract and ecologically valid stimuli have different benefits and examine different aspects of early vision when used within backward visual masking experiments. However, ecologically valid stimuli are more difficult to mask in that the stimuli can vary greatly in contrast, spatial frequency, orientation and colour across one image. This makes the choice and justification of a mask more complex as the masking stimulus will have to interrupt the processing of more than one image property. In the following sections the psychophysical aspects of distinguishing between target images and the selection of an appropriate masking stimulus are discussed in further detail.

4.5 Psychophysics and stimulus choice

In classical psychophysics there is an attempt to link a physical stimulus with our mental perceptions of the world via the use of measurements. In this thesis there is an attempt to link the mental perceptions of the participants with physical variations between stimulus types, i.e. patterns. Weber (1846: In Gordon, 1997) experimented on the perception of different weights and noted that there was a *Just Noticeable Difference* (JND) at which a weight could be identified as being heavier or lighter than another. Fechner (1860) extended the results of Weber and noticed that there was a geometrical increase in both the perception of weights and in the actual weights, in other words a link between the physical and mental world in the perception of sensations.
Similarly, comparisons between the salience of categorical stimuli such as pattern-types can be examined by comparing the amount of processing time, i.e. at what point a pattern is recognised. If a particular pattern type is more salient than another, this may be reflected in a different threshold processing time.

When applied to patterns, the brightness, contrast and spatial frequency may produce similar threshold effects. However, these threshold effects might produce confounds in identifying perceptual differences between categorical stimuli such as symmetry types. Instead a resulting threshold curve may only reflect the grouping or clustering of pattern elements, i.e. the proportion of light to dark areas, and not the categorical differences between two pattern types.

In threshold theory as proposed by Fechner in 1860 (Corso, 1970; Gordon, 1997) the brain is considered to be processing numerous random events as a stimulus is presented. This would mean that there is a threshold, above the random events, at which the stimulus is detected. This threshold can be explained in part by signal detection theory (Green & Swets, 1966; Tanner &

Swets, 1954) and by information theory (Shannon, 1948) in that the random events within the brain (or other functions) can be considered as background noise, therefore for stimulus detection to occur the event has to be of a particular magnitude to be detected. The function that is altered could be the time allowed for processing, so that if a stimulus is presented for a particular duration then there is an increased or decreased chance of the image being identified above other random events, such as a masking stimulus.

Threshold detection can be applied to pattern perception in that the perception of each pattern type will, in theory, occur at different times within the visual system. This will mean that for recognition to occur different presentation durations would be required for different pattern types. Therefore when salience or accuracy of the pattern is plotted against processing time different pattern types will produce different ogive threshold graphs similar to the one presented in Figure 4.1.

In the modern psychophysical method (Gordon, 1997) one constant stimulus is compared against a set of other comparison stimuli across several trials. The adjustment method involves manipulating the comparison stimuli until they match the constant stimulus in terms of the responses that are produced. For example adjusting the brightness of one stimulus until it is the same as a control stimulus. In an adjustment method the participant alters the stimuli themselves until the match is made. The psychophysical method is based on Guassian theories of probability, where more and more random events are accounted for under the curve of a normal distribution until the probability for the comparison stimulus, the area under the graph, matches that of the control stimulus. When this is expressed as a graph, this will resemble a curvilinear or ogive graph i.e. the cumulative probability function (Figure 4.1). The manipulation of the stimulus by the participant provides an accurate measure of that person's threshold, however this is reliant on the expertise of the individual participant. In this thesis the participant does not carry out the manipulation of the processing time. The intention is not to identify a specific modality for one participant's perception of a pattern or face but to identify whether there are general trends towards different biases within the human visual system. Therefore participants were provided within the masking methodology with a variety of processing intervals over repeated trials and the mean accuracy in recognition recorded as a dependent variable.

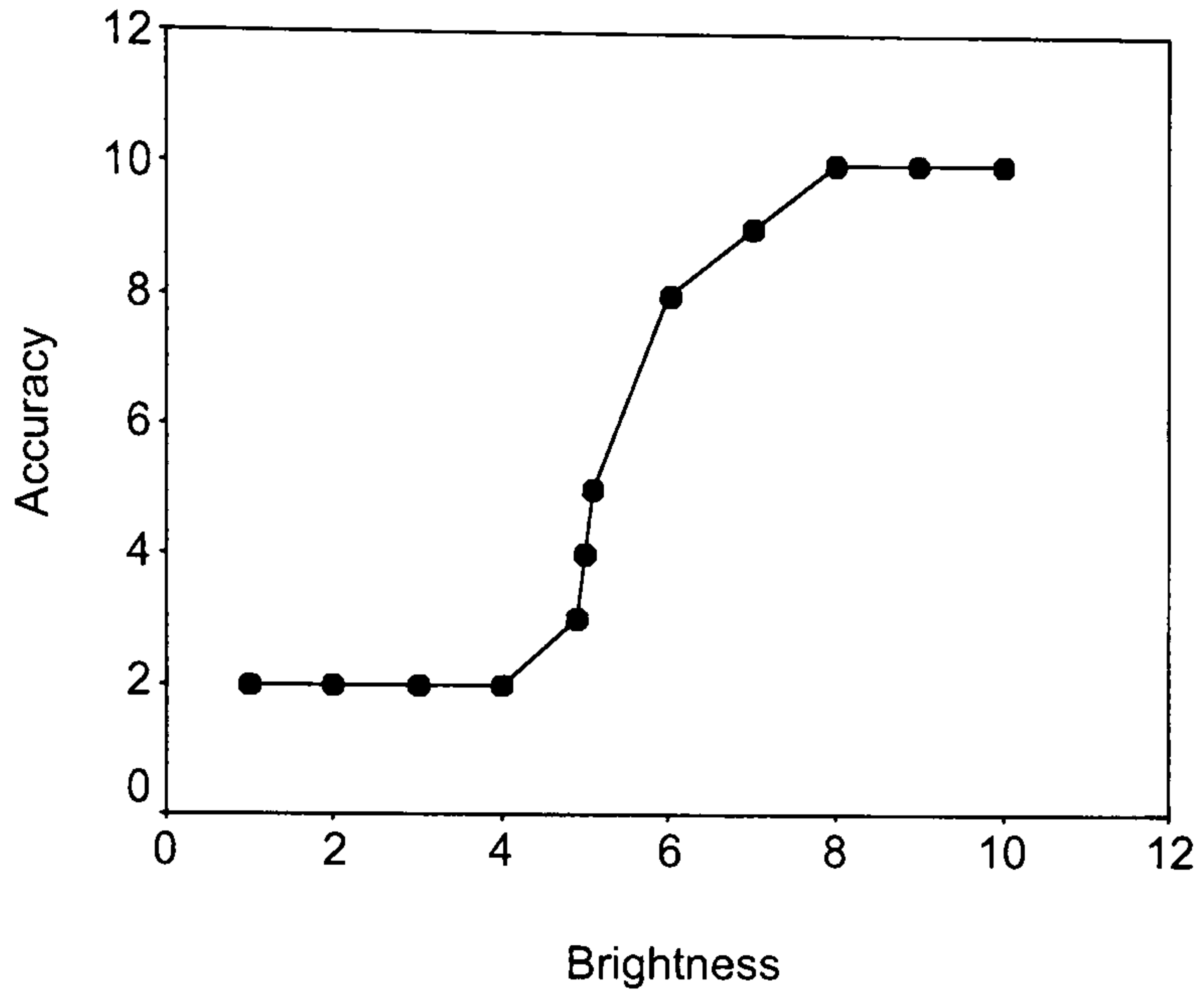


Figure 4.1: Example of threshold curve for improvements in accuracy in relation to changes in an arbitrary measure of brightness in a brightness-matching task

Although threshold theory provides a useful framework for examining the saliency of a target stimulus it is necessary to consider other variations of threshold theory. One such variation is that of the Neural Quantum Theory formalised by Stevens, Morgan and Volkmann (1941). This theory assumes that the neural mechanisms underlying discrimination are functionally distinct or discontinuous. These discrete neural mechanisms are called neural quanta. If considered as boxes each of these quanta is filled when a particular amount of energy associated with a particular stimulus as it is presented. The all or nothing state of the quanta is also subject to variation in sensitivity characteristic to neural systems. These determine threshold performance although as described above this would provide a straight line all or nothing graph (Figure 4.2).

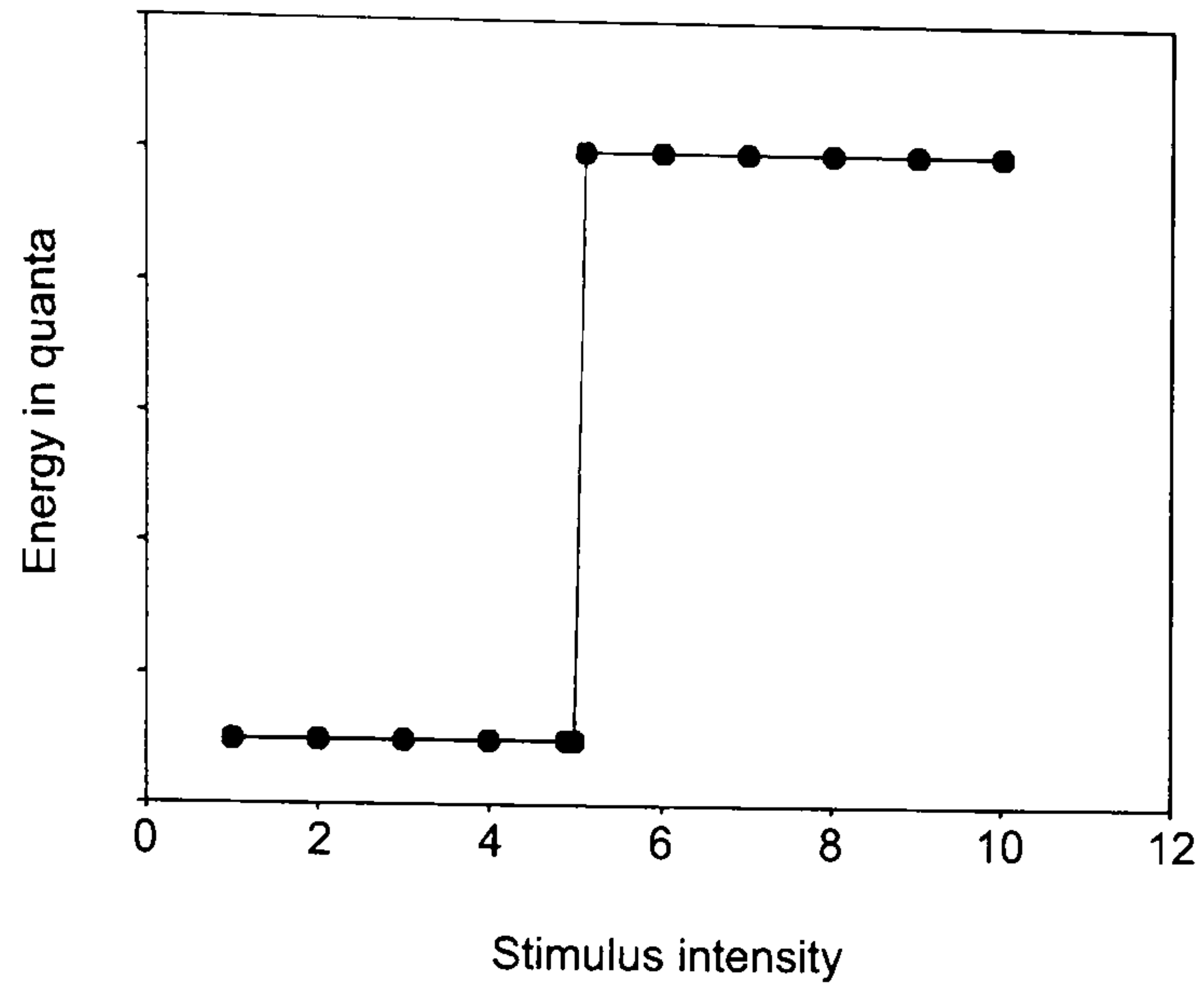


Figure 4.2: The quanta all-or-nothing threshold

The neural quantum theory is more applicable to studies that are focused on behaviour at the neuronal level. In a pattern perception experiment the participants would have to wait until the right amount of quanta are activated or filled so that they can make the choice that there is a difference between stimuli. One major problem is that practiced observers have to be used in such experiments to maximise the internal validity, as they need to be able to focus solely on the stimulus presented and block out the irrelevant stimuli, i.e. reduce noise. This limits the sample that can be used and reduces the external validity of the experiment in terms of applying the findings to the natural world.

In the construction of pattern perception experiments the threshold curve provides an appropriate and desirable form of comparison between different patterns as long as possible confounds such as spatial frequency, brightness and contrast are considered. Examining the stimuli in terms of a signal threshold also allows for the use of related methodologies such as signal detection theory. Varying processing time allows for the identification of a processing threshold and therefore differences in saliency between patter-types. However to ensure that the processing time is interrupted at a specific point a masking stimulus that can supersede that of the target pattern is required.

4.6 What mask should be used in backward masking?

Crucial to any masking procedure is the choice of mask. Hellige et al. (1979) suggest that the mask properties play a large role in the effect and conclusions reported in backward visual masking experiments. The types of mask that can be used include brightness masking, meta-contrast masking and pattern masking. In this thesis there is a focus on pattern masking as the choice of mask is intended to hamper the visual processing of a variety of different stimuli. Turvey (1973) suggested that pattern masking disrupts processing by being peripherally integrated with the target and also disrupts the target identification by being structurally similar. Optimum masking can therefore depend on the degree of similarity of the mask to the target by maximising integration effects. However, the mask should be designed to break up the contours of a target stimulus in either an additive way by combing all the target stimuli into one image, or by a disruptive way by overlapping the edges of the target stimuli (Kovacs et al., 1995).

However, the similarities between the target and mask can be described either in terms of their spatial-frequency and energy properties (Blakemore and Campbell, 1969) or in terms of their figural description within the Euclidean space (Caelli & Moraglia, 1987). For abstract patterns, e.g. simple gratings, the masking effects can be predicted by the use of spatial frequencies as the amount of information present within such stimuli are carefully controlled (Harvey & Doan, 1990; Kammer, Scharnowski & Herzog, 2003). However, for 2 dimensional images that contain a specific meaning or are of ecological validity there is a bias towards the use of figural-based descriptions in the choice of mask. Despite some criticism of the use of figural descriptions (Delord, 1998) they provide a way of identifying structural similarities and attributes that cannot be accounted for by spatial frequencies alone. However, considering the spatial frequency of an image, even in simple terms such as the size of the constituent elements, can in conjunction with figural descriptions help to provide a repeatable procedure and justification for a particular mask choice.

There is evidence to suggest that the spatial frequency of a pattern mask will also reflect which aspect of the target image will consequently be masked (Delord, 1998). For example a pattern mask containing a low spatial frequency, i.e. large elements, will be more successful at masking the global features of an image. Conversely a mask that contains a high spatial frequency, i.e. smaller elements, will be more successful at masking the local features of an image. This provides a particular problem for the masking of patterns where both the global and local features are to be masked. In this thesis two distinct symmetry types were examined, reflective symmetry that is suggested as being perceived at a global level, and repetition that is suggested as being perceived at a local level. Therefore either multiple masks need to be used for each stimuli or a mask that can disrupt both the local and global features of the image.

When a target is a more ecologically valid stimulus containing a variety of features that need to be masked, for example a face, then the choice of mask has to disrupt visual processing of both the local and global features. Tieger and Ganze (1979) suggested the use of a mid-frequency mask, as the spatial frequency band conveys the information about the salient features of the face such as the eyes and mouth. Therefore a mask consisting of random medium sized elements would be expected to work best. For example, Ingjaldsson et al. (2003) in their study of preattentive processing of alcoholic stimuli by alcoholics used a pattern mask that comprised of randomised pieces of the target picture, i.e. 2 bottles of beer.

However masking has also been shown to work with just a change in luminance, i.e. a target is followed by bright light (Crawford, 1947; Spencer & Shuntich, 1970; Sperling, 1965). Luminance differences between the mask and target are therefore also important considerations. For some masks to work there has to be a disparity in the contrast between the target and mask, for example in meta-contrast masking procedures. So a high contrast mask (compared to the target) will have a greater effect (Breitmeyer, 1978). The use of high contrast masks and luminance differences between the mask and target result in an interruption of the processing of the target. Therefore, the energy of the mask can be identified as being an important property in the disruption of the visual processing of the target stimulus (Breitmeyer 1984). The energy of a mask is defined as the multiplicative effect of the duration of the mask and the intensity (i.e. contrast and brightness properties) of the mask.

Francis (2000) suggested that the energy of mask might result in the production of different types of masking effect as illustrated by the graphs in Figure 4.3. When comparing the ways in which different target stimuli are processed or how different types of participants respond to masking procedures it is important to guarantee that the same variable is being measured. Changes in the mask intensity or energy, perhaps in relation to a target stimulus, or variations in mask duration might have an effect on the type of masking curve produced (Figure 4.3). This will reflect whether the mask has interrupted the processing of the target stimuli at an early stage of processing or whether the mask is disrupting the target at later stages of processing. One frequently presented type of masking curve is that of the U-shaped curve where there is an optimum ISI or SOA where the recognition of the target stimuli is lowest. If during experiments there is a shift in the position of the optimum interval then there is likely to be an effect caused by the mask. A weaker mask, i.e. one of low intensity and short duration, will result in a shifting U -shaped distribution for the different targets being masked (see Figure 4.3).

However, if the position of the optimum interval does not change but the degree of recognition does, i.e. the base of the U -shaped curve remains in the same place along the x-axis while the position changes along the y-axis, masking can be concluded to be the result of perceptual strength effects from the target (Francis & Hermens, 2002). Francis and Herzog (2004) suggest that the U-shaped curve could be the result of a weaker masking effect and the monotonic masking functions are the result of stronger masking. An example of both types of graphs is shown in Figure 4.3. These factors have to be considered in the interpretation of any graphs generated by masking experiments, as there is a possibility that there could be variation in the degree of integration and interruption between target stimuli. For the purpose of this thesis a graph shape similar to that presented in Figure 4.3, graph b would be preferential, as it would reflect differences in the perceptual strength of the target stimulus, i.e. differences in the responses as a result of the symmetry type not as a result of the mask energy.

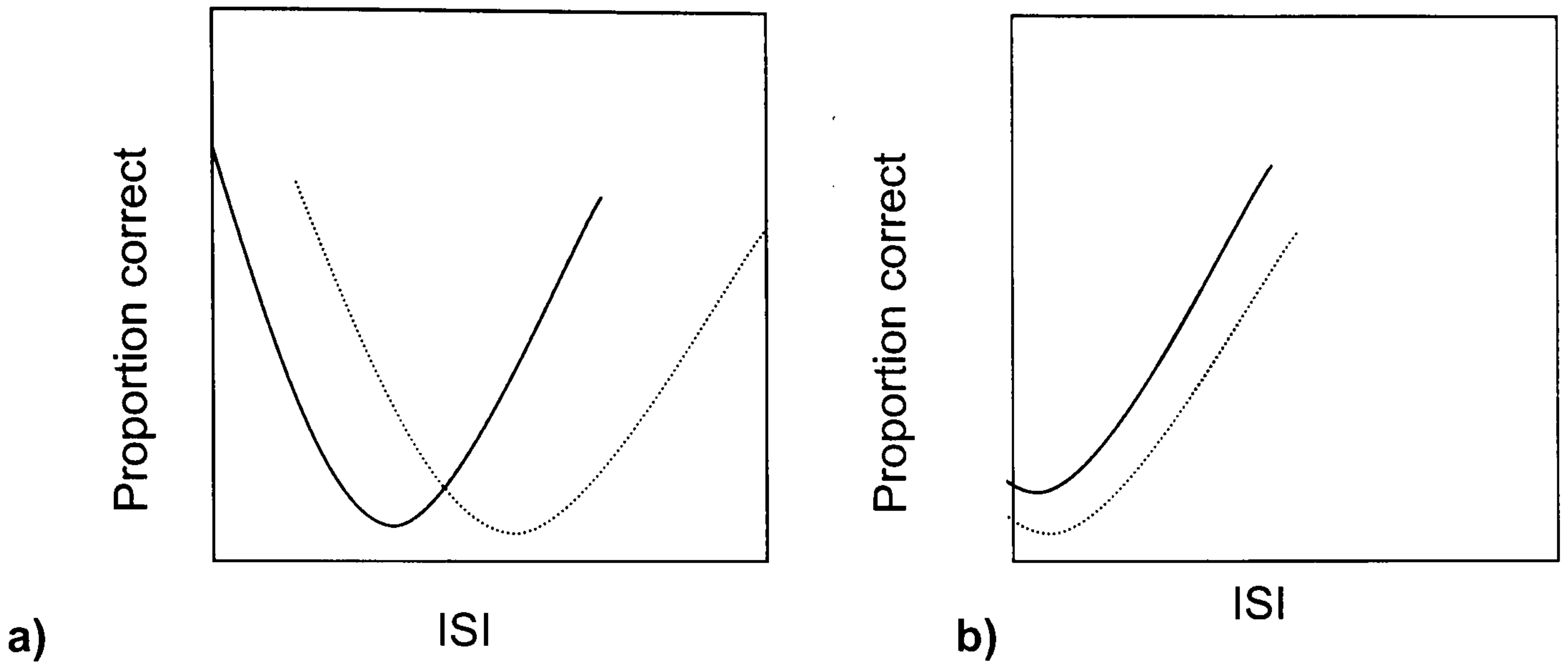


Figure 4.3: a) Change in ISI = changes in mask properties; b) Change in proportion correct = change in perceptual performance of subject or target.

For this thesis several different types of masking are combined to provide a maximal effect. In the abstract masking experiment, masks that can hamper perception of both the global structure and local structure are required. Therefore the masking stimulus is required to contain elements that will disrupt the low spatial frequency global properties and the medium frequency local properties. The intensity of the mask is also important and by presenting the target stimulus on a grey background and using a black and white, i.e. high intensity, masking stimulus should maximise interruption effects (see Chapter 5, section 5.5 for examples). For the ecologically valid face stimuli the global features, i.e. the shape of the head and hair, are not of interest, as the main goal of the experiment is not face recognition. Therefore masks that obliterate the local features of the face are utilised as these represent the features that are salient in the perception of facial symmetries (see Chapter 6; section 6.4 for an example).

4.7 The choice of interval between the target and the mask

The definition of the interval between the target and mask shows great variation between differing masking methodologies and this may be of relevance when interpreting whether an experiment is examining the influence of the onset or offset of a target or masking stimulus on early visual processing. These intervals include the Inter-Stimulus Interval (ISI), Stimulus Onset Asynchrony (SOA) and the Stimulus Termination Asynchrony (STA), see Figure 4.4 for diagram illustrating the three intervals. The ISI is the interval between the termination of the target stimulus and the initiation of the masking stimulus. The ISI assumes that processing of the target stimulus continues after termination of the target stimulus until the point when the masking stimulus is introduced, i.e. the onset of the masking stimulus. The SOA is the time interval between the onset of the target stimulus and the onset of the masking stimulus. Therefore the SOA is useful in that it takes into account the onset of the target stimulus and target duration. However, in methodologies where the target duration remains constant and the ISI between the mask and target is varied, the SOA can be calculated by the addition of the target duration to the ISI. The STA is the time interval between the termination of the target stimulus and the termination of the masking stimulus (see Figure 4.4 below). However, the STA does not take into account variations in the duration of the target stimuli, but does describe masking effects as the result of variations in mask duration.

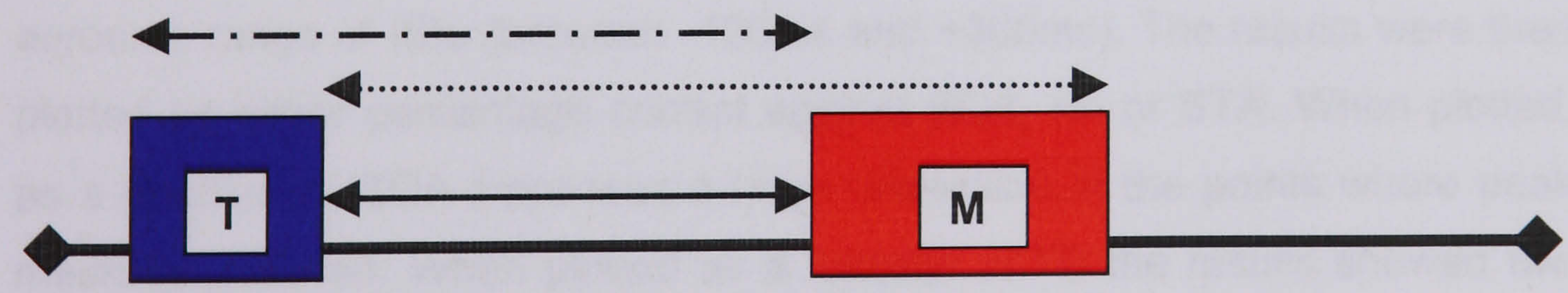


Figure 4.4: Example of the timeline for masking experiments and the characteristic measures of interval. T = target, M = mask

= ISI, ←——→ = STA, ←·········→ = SOA. ←—·→

The interval between the target and mask is of critical importance as the interval can be used to assess whether processing of the target has occurred up to a specific point within the visual processing system. Assuming that the processing of a visual stimulus continues for a period of time post presentation (Sperling, 1960; Turvey, 1973), the intervals selected should reflect the neurological evidence for the time course of visual perception (see Chapter 2). Therefore, when discussing these intervals it is important to use the appropriate description, ISI, SOA & STA.

The SOA and ISI are the most frequently used interval descriptions as they allow for the discussion of the total time that is available for the processing of the target before the interference of the mask (Green et al., 2003; Rolls et al., 1999; Kovacs et al., 1995; Hellige et al., 1979; Michaels & Turvey, 1979; Rolls & Tovee, 1994; Ward & Duncan, 1996). However, neither the SOA nor ISI take into account the duration of the masking stimulus and the effect that this might have on the masking effect.

Macknik & Livingstone (1998) compared results from a visual masking experiment that took into account the interval between the mask and target in terms of the SOA, ISI and STA. In their masking experiments, Macknik & Livingstone examined the effect of pattern masking on participant's ability to distinguish the comparative length of two bars. The duration of the target was 20, 40, 90, or 140ms and the mask duration was either 50 or 90ms. These were presented in 6 different combinations and presented to the participant across a range of ISIs (between -100ms and +300ms). The results were then plotted as either percentage correct against SOA, ISI or STA. When plotted, as a function of SOA there was a large dispersion in the points where peak masking occurred. When plotted as a function of ISI the results showed two significant peaks one representing forward and one representing backward masking, there was little variation between the 6 conditions. When the results were presented as a function of the STA there was again little dispersion between the conditions with peak masking occuring at an STA of 100ms. These results suggest that either the STA or ISI provide the most accurate descriptions of when masking effects are occuring.

In this thesis the duration of the target stimulus and the masking stimulus are kept constant throughout the trials and therefore the ISI reflects the variable that is being altered and is the measurement that is reported.

4.8 General Method

A backward visual masking paradigm was selected in order to interrupt the continued visual processing of the target stimulus. The following basic methodology applies to all the masking experiments in the present investigation. The apparatus applies to all the computer-based experiments. The choice of stimuli and the choice of mask are described in the methodology of each of the individual experiments.

4.8.1 Stimuli

All of the stimuli used were 2-D patterns presented in greyscale. The patterns were either abstract checkerboard patterns or natural patterns, i.e. faces. The choice of each target stimulus and masking stimulus is described in detail in the introduction to each of the main experiments (Chapters 5 to 7). Due to the wide range of pattern types being masked for each of experiments, pattern masks were used (see Appendix A for list of target and masking stimuli).

4.8.2 Apparatus

The experimental area was 2.35m x 2.75m with a blacked out background and the ambient light maintained at approximately 0.9 Lux to reduce glare on the screen. Participants were seated between 60cm and 70cm from the display and asked to make themselves as comfortable as possible before the experiment started.

The experiment was run on a Viglen 500MHz computer with a Pentium 4 processor, the screen used was a Viglen 17" TFT multimedia monitor with a refresh rate of 75.0059 Hz and a refresh duration of approximately 13.333ms.

Prior to each experiment the computer refresh rate was tested using a Refresh Clock experiment (E-Prime 2002). The screen area was 800 x 600 pixels and the display in 16-bit colour. The experiments were constructed and run using E-Prime psychology software version 1 (2002).

To reduce after-image effects a grey background colour was selected and the brightness set to 29% and the contrast 70% on the monitor settings. The experimental stimuli were created using Adobe Photoshop CS version: 8. All stimuli were presented in greyscale to eliminate any confounds due to colour.

4.8.3 Procedure

Prior to the experiments participants were told that they were taking part in a pattern or face detection experiment and then asked to sign a consent form (see Appendix H). Background noise was reduced to a minimum throughout the experimental procedure. The basic masking experiment involved participants identifying whether a response image presented after the mask was the same as the target stimulus presented prior to the mask (see Figure 4.5). All of the trials were counterbalanced so that there was always a 50/50 chance of success. This was achieved by presenting a 'no change' condition for every 'change' condition. The experiments were a within-subjects design with all participants taking part in all of the trial conditions. All of the trials were randomised in their order of presentation so that there would be no order and carry over effects.

It was important that the participants were aware that there would be an image presented prior to the masking stimulus and were familiar with the procedure before the main trials, therefore prior to the practice trials the masking procedure was explained to each participant. Once participants were seated in the testing area and comfortable with the instructions they were left to work their way through the blocks of trials without any interference from the researcher, the researcher would only intervene at the participants request or if the participant was taking a particularly long time to complete a block of trials. This was to try and reduce any distraction or good participant effects, where the participant feels they should behave or respond in any one particular way. The researcher remained close by in case the participant needed any help or had any questions.

Throughout the experiment the participant followed a series of instruction screens. The first instruction screen introduced the basic keys and procedure of the experiment.

"You will be shown an image [face or pattern] followed by a masking image.
Then after a few seconds a second image [face or pattern] will be shown
Press '1' if the first image is IDENTICAL to the last.
Or Press '2' If they are DIFFERENT.
Press space to continue"

Instruction screen 2 presented an example of the masking image so that the participant could become familiarised with it. This was to prevent any confusion identifying between the target and the mask. This was followed by a slowed down example of a possible trial sequence. Instruction screen 3 reiterated the keys mentioned in instruction screen 1 and introduced the practice trials and encouraged the participant to ask the researcher if they had any questions regarding the procedure. Participants could then start the practice trials as soon as they were comfortable.

The practice trials varied in number for each participant as the participants had to achieve 80% correct. Each run of practice trials consisted of 16 trials. If the target percentage was reached the participants were given the opportunity to continue with the main trials. If the percentage was less than 80% then the participants were required to repeat the trials. The practice trials were run with a constant ISI of 500ms. This duration was selected as this would allow for the complete processing of the target stimulus and provide participants with enough time to scan the image. The practice trials allowed participants to become familiar with the procedure and keys while not actually allowing the participant to experience the full masking effect. This meant that all participants were of equal familiarity with the procedure before starting on the masking trials. This was to reduce any practice effects and start all the participants at the same level of expertise during the data collection trials. Once the participant had started the practice trials the researcher left the experimental cubicle but remained close by in case of any problems. Once the participant was comfortable with the procedure and once the main trials had begun the researcher left the experimental area to lessen any external influences on their behaviour.

Prior to starting the main trials participants were warned that the target images might appear to be presented at a faster rate than in the practice trials. This was to prevent participants panicking when faced with the change of pace. The order in which the main trials were presented was randomised within each block, this prevented participants from predicting when a stimulus would be presented and any priming effects (see Figure 4.5 for an example of a trial).

Each trial followed the same basic pattern of presentation (see Figure 4.5 for an example). At the start of each trial the fixation screen was presented for 900ms, followed by a 100ms delay and then the target image. The target image was then presented for 13.3ms, the equivalent of one refresh of the computer screen this ensured that each image was presented in its entirety and not half a screen at a time. If the target were presented for any longer than this duration then there was the possibility of the target being presented for two refreshes of the screen.

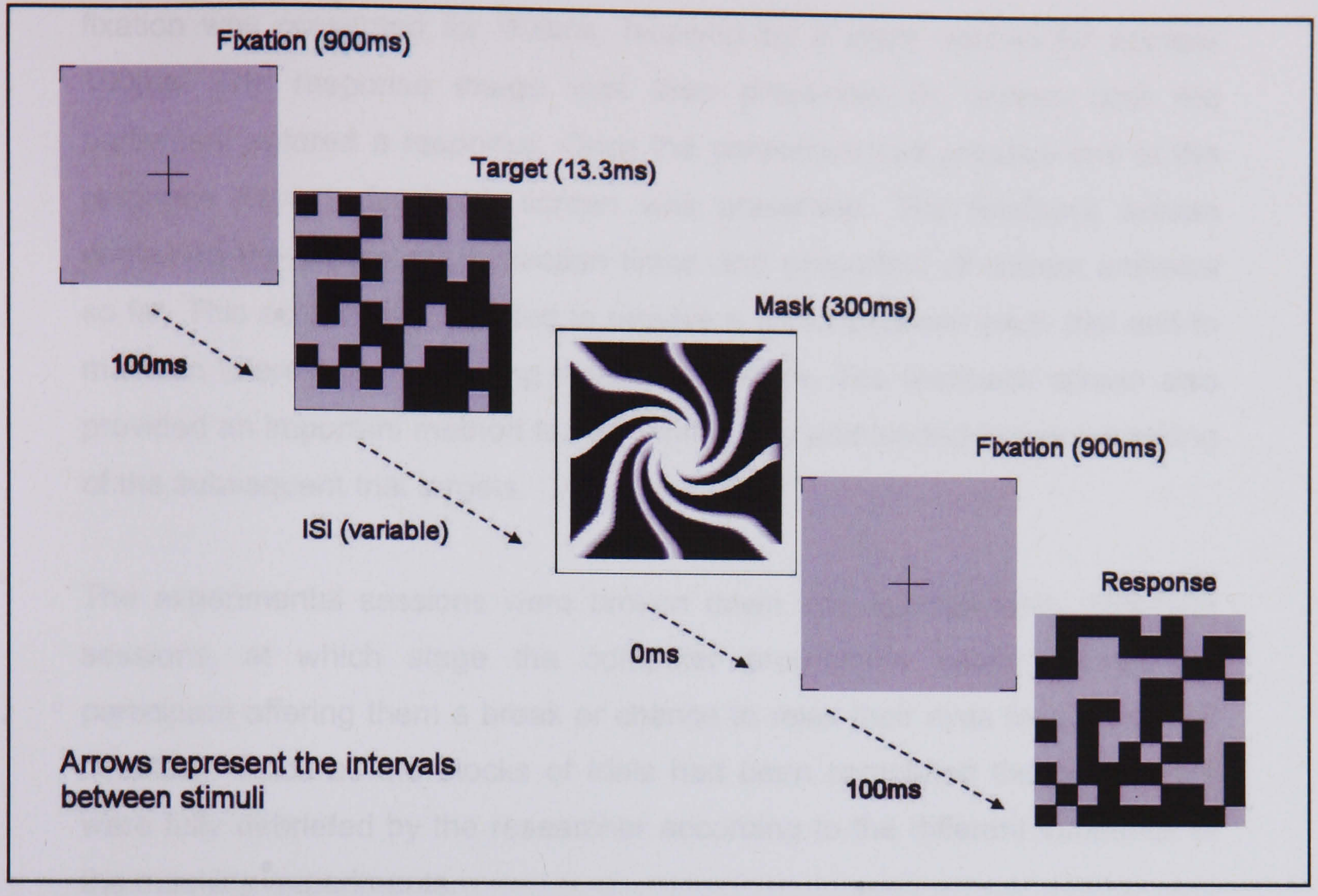


Figure 4.5: Time course of the masking experiment. The sequence of events was maintained for both the abstract pattern experiments (as above) and for the face experiments.

The target image was followed by a variable ISI depending on the trial condition. To reduce any timing errors all target images were preloaded during the fixation display, this in turn maintained a constant ISI duration. Therefore the fixation point was presented for 900ms. During data collection the duration of the ISI and target presentation were recorded. If there were any delays greater than one screen refresh, >14ms, then the trial would not be used. However, in preliminary tests there was less than 1% error in the timing of the computer.

After the ISI the mask was presented for 300ms, this was in order to obliterate any on going processing of the target image and redirect attention. This duration is considerably longer than the optimum STA identified by Macknik and Livingstone (1998), this was to ensure that maximal masking had occurred and that the target stimulus had been fully interrupted. The second fixation was presented for 900ms, followed by a blank screen for another 100ms. The response image was then presented on screen until the participant entered a response. Once the participant had pressed one of the response keys a feedback screen was presented. The feedback screen contained the participant's reaction times and proportion of correct answers so far. This screen was inserted to provide a break between each trial and to maintain interest during a long testing procedure. The feedback screen also provided an important method for preventing any unintended forward masking of the subsequent trial targets.

The experimental sessions were broken down into approximately 10minute sessions, at which stage the computer programme would prompt the participant offering them a break or chance to relax their eyes for a couple of minutes. Once all the blocks of trials had been completed the participants were fully debriefed by the researcher according to the different variations of the masking experiments.

4.9 Analysis

Several different methods of analysis were used depending on the type of variable tested and the type of data collected. For the abstract (checkerboard) masking experiments each target stimulus condition was counter-balanced with a change or no-change condition. These data were therefore suited to signal detection theory providing a valuable measure of not only the accuracy but also any response bias within the data (i.e. whether there was a tendency for a participant to predominantly assume that a change had or had not occurred to a test stimulus). In the face detection experiments signal detection theory was not used as the number of trials were minimised to maximise the range of trial conditions and participants (see Chapter 6). In these situations the trials were repeated several times for each condition and the mean proportion of answers correct was used in further statistical tests. In experiments where the sample size was below 8 and the data did not fit parametric criteria, the data were examined using randomisation tests to reduce any autocorrelation effects and provide a robust statistic test compared with non-parametric alternatives. In the following sections the method of signal analysis, and outlines of the statistical methods used are briefly discussed.

4.9.1 Signal Detection Theory

Signal detection theory allows for the examination of responses in psychological tests in terms of the probability of getting a correct response weighted against false responses (Swets, 1961; Green & Swets, 1966; McNicol, 1972; Macmillan & Creelman, 1991). The benefit of this methodology is that it allows for the examination of the accuracy of responses and takes into account the responses of a participant to false stimuli, i.e. it enables the calculation of hits, misses, false alarms and correct rejections (Table 4.2). Figure 4.6 shows the responses to a forced choice task, the right hand curve represents the number of times the participant believes that there is a signal and the left hand curve represents the times when a participant believes that there is not a signal. The overlap between the graphs represents the area of uncertainty that can be described in terms of misses and false alarms. The difference between the two peaks is the accuracy (d').

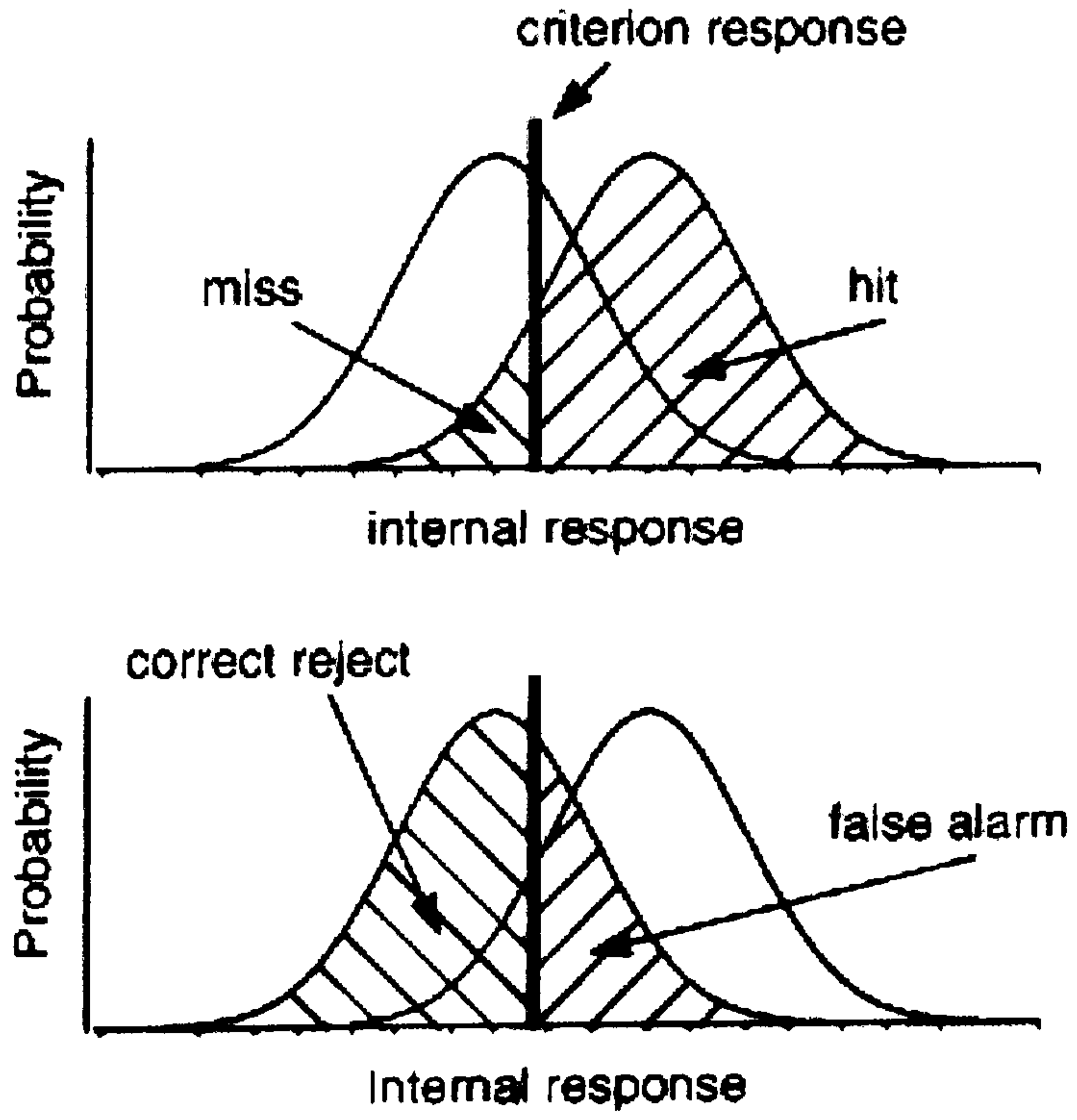


Figure 4.6: Normal distributions illustrating signal detection theory in terms of hits, misses and correct rejection and false alarms.

Signal detection theory (Green & Swets, 1966) is based on the premise that observation minus noise will equal the strength of the signal. This is useful when examining threshold properties for different stimuli. This method of analysis is also useful in examining experimental output that consist of a binary forced decision, i.e. true or false and yes or no. Table 4.2 illustrates how the binary choices can be presented in the form of a decision matrix highlighting the differences between false alarms, when a signal is said to have been detected when none is present and the miss where a signal is present but not detected.

Table 4.2: The matrix of responses from a participant within a signal detection theory design.

Participant response

Correct answer	**YES**	**NO**
YES	HIT (correct)	MISS (incorrect)
NO	FALSE ALARM (incorrect)	CORRECT REJECTION (correct)

In order to calculate d', the measure of accuracy, and c, the measure of response bias the data obtained from the experiments are entered into an SPSS spreadsheet (Figure 4.7). In the following section the method of calculation in SPSS is described in detail.

participant	**hits**	**misses**	**f_alarm**	**c_reject**
1				
2				
...n				

Figure 4.7: method for data entry into SPSS

The hit rate is calculated by entering the following expression in to the 'compute' facility. ‘h_rate’ was entered into the target variable box and in the numeric expression box '(hits+0.5)/(hits+misses+1)' was entered. The false alarm rate was again calculated using the compute function. ‘f_rate’ was entered into the target variable box and in the numeric expression box '(f_alarm+0.5)/(f_alarm+c_reject+1)' was inputted. These expressions provided two columns of data for the hit rate and the false alarm rate. From these 2 measures it was possible to then calculate the accuracy (d’).

Using the compute variable function ‘d’ was entered as the target variable and in the numeric expression box the following function was entered '(IDF.NORMAL(h_rate,0,1)-IDF.NORMAL(f_rate,0,1)'. This provides a column of data for accuracy. The higher the value for d’ the more accurate the response is. This data can then be analysed using standard statistics such as t-test, within subjects ANOVA or a non-parametric equivalent.

Another useful measure to obtain is the bias (c). This provides a quantitative measure of how biased the participant is to one particular type of response. Using the compute variable box in SPSS, 'c' was entered as the target variable and the following was entered into the numeric expression box, '0.5*(IDF.NORMAL(h_rate,0,1)-IDF.NORMAL(f_rate,0,1)'. This provided a column of data for the bias in response where a negative value for C denotes a bias towards saying yes, i.e. a false positive response, while a positive value of C denotes a bias towards saying no, i.e. false negative.

In designing an experiment to suit SDT, the presentation of a stimulus has to be balanced so that there are equal numbers of correct acceptance and correct rejections. This methodology can then be used to try and establish whether the participant can detect a briefly presented stimulus that is subsequently masked.

4.9.2 Randomisation methodologies for sample with small-n

With small-n designs, those with sample sizes less than 8, it is difficult to be confident that the assumptions for parametric testing such as a normal distribution and homogeneity of variance can truly be met (Siegel & Castellan, 1988). Therefore methodologies that require obtaining large amounts of information from a small number of participants might not be reflective of the population that they are sampled from. Randomisation of the order of trials and events presented to participants is therefore essential to avoid autocorrelation based on variations over time. By autocorrelation we mean that in small sample sizes an apparent change, or relationship between variables can be observed when none actually exists. This is particularly a problem in response-guided methodologies that are reliant on graphical analysis of data, the advantages of response guided experimentation is that the experiment can be changed or tailored towards the participant and allows for the progression of a study and removal of conflicting variables as an experiment progresses. However such designs have reduced internal validity so randomisation has to be included in order to reduce autocorrelative effects and maintain the internal validity of an experiment. Backward masking experiments generally have a high internal validity in that many of the conditions can be controlled however in a multi-participant design this becomes a partial confound as different people respond differently to the same conditions. Randomisation helps to eliminate such issues and questionnaires checking on what variables are influencing the participant outside the experiment are of use.

With small sample sizes non-parametric tests can be used but these can lead to a loss of information by changing the actual data in to ranks. However, if there are insufficient data conclusions about their distributions cannot be made in order to justify parametric testing. The alternative is to use randomisation procedures that assume all the information regarding the distribution is present in the data. A randomisation test can then be used to examine whether the data support or do not support a null hypothesis. The randomisation test works by testing all possible arrangements of the data rather than the final order collected from the experiment. So for example accuracy for a visual memory test in one condition, e.g. rapid presentation rate, could be compared with the accuracy under an alternative condition, e.g. slow presentation rate. Rather than comparing the result in the order they are collected the randomisation test will calculate all possible combinations of the data and test each variation to see if there is still a significant difference between the two conditions or whether there has been an autocorrelation due to presentation order (Todman & Dugard, 2003).

So in the design of the following experiments the appropriate statistical analysis will be chosen on the criteria that for sample sizes greater than 8 parametric tests will be used if the conditions are met otherwise non-parametric equivalents will be used. For sample sizes smaller than 8 randomisation tests along with traditional non-parametric tests will be used. However, if there are any differences that appear to be clear in the graphic interpretation but not reflected in the traditional analysis randomisation tests can be used to reorder the data and see if conclusions are accurate under all interpretations.

All experiments will be presented in a randomised fashion rather than a phased presentation in order to increase the internal validity and suitability for randomisation testing if necessary. The benefits with randomisation tests is that when an experiment is labour intensive therefore limiting the recruitment of participants, then the results can be applied with more confidence and the external validity of the result is increased. This is especially important in visual cognition experiments that often assume that as the rate of key pressing in response to an experimental stimulus is a direct result of that stimulus then statistics are not necessarily needed to extrapolate a causal connection between the two variables. In other words there is high internal validity as they can be confident on a action is the response of the other. However if trying to see if this response is different for stimuli that might be considered subjective e.g. perception of different pattern types where aesthetics could be an issue, then randomisation testing would add weight to the conclusion drawn from a small sample size.

4.9.3 General statistical analysis

The types of experiments carried out in this study were all within participants repeated measures design. Therefore within participants one-way and two-way ANOVAs were used when the parametric requirements of homogeneity of variance and normal distribution were satisfied (Brace, Kemp & Snelgar, 2003; Howitt & Cramer, 2005). However when the parametric conditions were not available then an appropriate non-parametric test was used. All the tests used were two tailed as this reduces the likelihood of type 2 errors, and does not make assumptions regarding the directions of any observed effects (Shaughnessy & Zechmeister, 1985). However if the sample size was small, less than 15 participants, then randomisation tests were used as they control for autocorrelation effects and provide a stringent suitable alternative to non-parametric tests that are applicable to within subject design experiments.

4.10 Conclusion

In conclusion the experiments were constructed in such a way that there is a forced choice paradigm with a 50/50 chance of guessing a correct answer so that signal detection theory measures of accuracy can be calculated (in particular in the pattern perception experiments). For the other experiments that involve face perception, the stimuli will still be presented in a 50/50 format but due to the fact that the conditions cannot be so clearly separated, e.g. a face that loses its eyes or a face that loses a mouth will share the same control i.e. the complete face, signal detection was not used but appropriate statistics that are compatible with within subject designs were used.

However all the experiments will be randomised in the order of presentation to reduce priming or cueing effect and allowing for justified use of signal detection and if needed randomisation methodologies. This is particularly appropriate when the sample sizes are small and obtained opportunistically from a convenient population.

Chapter 5: Investigation into the differences in early processing of repetition and reflection in abstract visual patterns

5.1 Introduction

The experiments reported in this chapter were designed to investigate whether patterning involves early phases of visual processing or requires subsequent higher-order processing. The following experiments investigated which characteristics of a briefly presented checkerboard pattern are perceived within a backward masking paradigm. The backward masking methodology allows for the interruption of the processing of a target stimulus either during the predominantly feed forward processes within the first 60ms (Bullier, 2001) or 120ms after stimulus presentation (Oka & Ejima, 2001) or during the later re-entrant processing between non-striate and striate areas of the cortex.

5.1.1 Masking and pattern detection

Evidence from event related potentials (ERPs) suggest that visual information is processed within the primary visual areas V1 and V2 after approximately 40ms to 60ms post stimulus presentation (Bullier, 2003, 2001; Thorpe & Gautrais, 1996). Therefore if a mask is presented around 40ms after the onset of a target image there will be some processing of the target within area V1 prior to the masking stimulus catching up and interrupting further processing. Therefore information from the target image will be made available to other vision related brain areas.

Visual information that is masked within 30ms of the onset of the target stimulus will only be made available to subcortical visual areas such as the LGN and superior colliculus prior to the interrupting effect of the mask (Thorpe, Fize, & Marlot, 1996). Therefore masking of a stimulus prior to this point should have a significant disrupting effect on the further processing of visual stimuli. The effect of the mask will be picked up in the peripheral visual areas when the target is reaching the primary visual areas and therefore re-entrant processing of the target will be interrupted prior to being categorised or recognised.

After latencies of 150ms there should be a greater accuracy in responses as the image will have been available for processing by other brain functions. Within 150ms the information needed to classify a stimulus has been made available to frontal, temporal and parietal areas suggesting that extensive re-entrant processing has occurred (Thorpe, Fize, & Marlot, 1996; Oka & Ejima, 2001; Sporns, Tononi & Edelman, 1991). However, the intervals between the target and masking images are not the only factors that will affect the accurate detection of the target stimulus. The relative salience and therefore the strength of the mask will also have a significant impact on the accurate perception of the target stimuli.

How and where the masking stimulus interrupts the visual processing is not entirely clear, therefore the saliency of certain image properties could result in a blending of the target and mask images. Alternatively if the mask is strong enough to suppress the properties of the target stimulus and interrupt further cortical processing, there could still be enough information present via the superior collicular pathways regarding the spatial qualities of the target to allow for accurate participant responses.

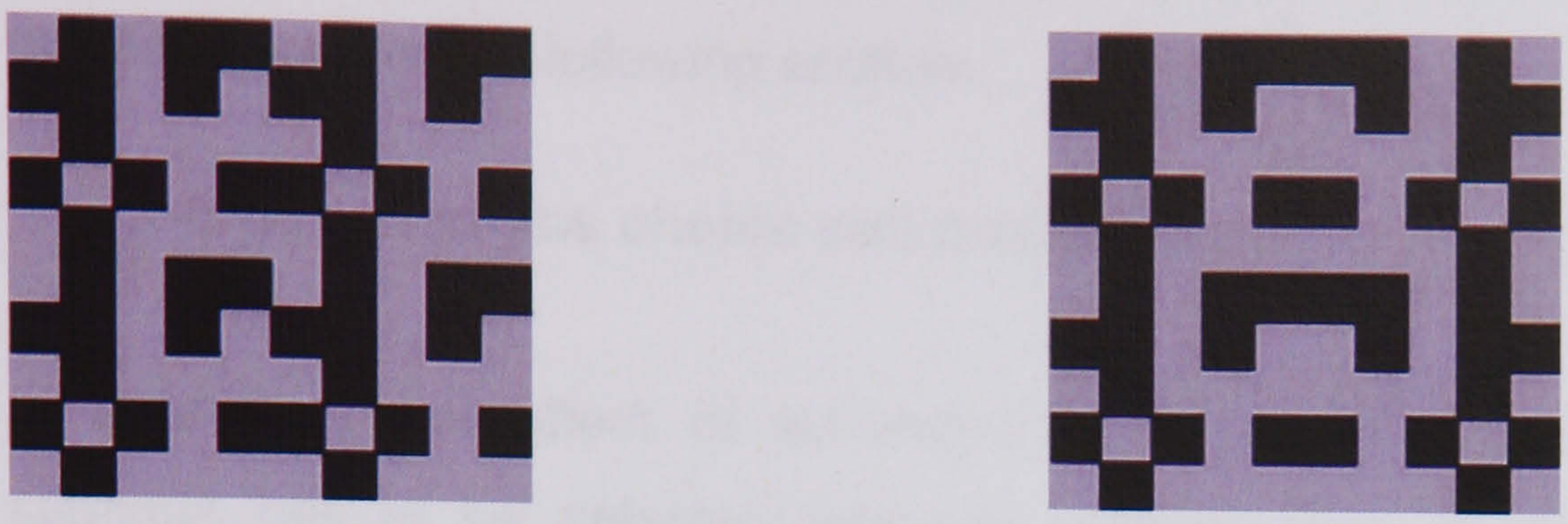
5.1.2 Properties of the target stimulus

Several different theories have been put forward to explain why certain patterns are more salient than others. The Gestalt theories (Eysenck & Keane 1990; Koffka, 1935; Wertheimer, 1912) suggest rules that are largely subjective and based upon the aesthetic appearance of an image. However as demonstrated in the pilot study (Chapter 3) aesthetic preferences are an important part of how people define patterns. Such aesthetic preferences could suggest a top-down processing strategy towards certain pattern types, as there are distinct preferences and biases for particular pattern types. This could reduce any masking effects at short ISIs as the visual system could be actively seeking certain pattern information in accord with participant preconceptions and preferences. However, as observed in the pilot study (see Chapter 3), there may be a predisposition for participants to prefer patterns that are informationally easier to process.

The introduction of information theory (Shannon, 1948) resulted in alternative explanations of what makes one type of pattern more salient than another based upon the information content of the image. Symmetry is one way of reducing the information content within a pattern. For example, by increasing the number of lines of symmetry within an image there is a reduction in the number of possible variations (i.e. information) of the stimulus after rotation and reflection (Handel & Garner, 1965; Attneave, 1954). Again the pilot studies (Chapter 3) suggest that patterns with a reduced number of possible variations are perceived as being aesthetically pleasing and an active part of defining a pattern. Therefore, the number of possible variants has to be incorporated into the design of the target in a masking experiment as a possible influence on the saliency of a reflective symmetry.

Symmetry type can therefore provide a method of reducing the information load on the visual system. For example, repeated and reflected patterns may contain information in their structure that reduces the cognitive load and provides one symmetry type with an advantage in the rate of visual processing over the other (van der Helm & Leeuwenberg, 1996; Baylis & Driver, 1995; 1993). In the following example the difference in the way repetition and reflection maybe processed is demonstrated via the holographic representational model (Chapter 1: Section 1.2). In this model reflection has an advantage in the rate of visual processing over repetition (van der Helm & Leeuwenberg, 1996; 1991).

In the example presented in Figure 5.1, the repeated pattern has 3 holographic elements ($E = 4 - 1$) and the reflected pattern has 22 holographic elements ($E = 44 / 2$). The number of stimulus elements (n) in these examples is 44. This represents the number of black squares in the patterns. The representational strength, i.e. salience, of each pattern can therefore be calculated utilising the "Weight of Evidence" formula: $W = E/n$.


a) Repeated pattern

b) Reflected pattern (with repetition)

Figure 5.1: Examples of repeated and reflected checkerboard patterns, each with 44 elements, i.e. 44 black squares.

Therefore, in this example, repetition has a representational strength (*W)* of 0.06818, whereas reflective symmetry has a representational strength of 0.5. This would suggest that in masking experiments, where the number of stimulus elements is within the range of 40 and 60 elements, there would be an expectation for reflective symmetry to be consistently more salient than the repetitive stimuli. Therefore in the above example of a pattern containing both reflection and repetition, the reflective properties will be detected first, i.e. will be more salient. However, the orientation of the stimulus will also have an effect on the perceptual strength of the stimulus (Julesz, 1981). This is a factor that is not accounted for by the holographic model and could have implications for the representational strength theory of reflective symmetry.

Alternatively repeated stimuli could posses an information advantage if the initial element has low information content and can be extrapolated across a larger field (Chater, 1996; Porthos & Ward, 2000). As suggested within the representational model a stimulus that possesses a greater number of repetitions would be processed serially and take longer to analyse than a reflected pattern. However, if the information were redundant as suggested by theories of simplicity (Chater & Vitanyi, 2003) then it would be expected that a pattern with multiple repeated elements could be recognised after very brief presentations. Therefore the number of repeats within a stimulus needs to be accounted for when examining the early visual processes of repetition. In addition, an appropriate target stimulus has to be selected in which not only the symmetry types are controlled but also other confounding factors, which are discussed in the following section.

5.1.3 Stimulus choice and properties

In examining the effect of symmetry type on early visual perception, a stimulus has to be selected that will increase the internal validity of the experiment, i.e. increase the degree of confidence with which it can be assumed observed differences in accuracy and reaction time are due to changes in the target stimulus. Therefore, in order to be confident that the property being investigated is only the pattern type, a stimulus that controls for differences in luminance, contrast and the grouping of elements has to be selected. Dot textures, and Gaussian filters provide stimuli that are useful in detecting reflection in that only the symmetry present within the stimulus can be detected and not the properties at the individual element level (Julesz, 1981; Dakin & Hess, 1997). However, if the experiment is comparing between repetition and reflection then there is a problem with texture based stimuli in that the elements that construct the image are not readily identifiable to the viewer. In repetition the identification of individual elements is necessary to extrapolate the pattern and find redundancy. However in experiments that require the matching of patterns by a participant then there is a need for the basic elements of the pattern to be identifiable so that if a participant chooses to scan an image serially they are able to do so. Textured stimuli although containing high internal validity are not readily identifiable when presented within a forced choice-masking paradigm.

By utilising a different type of pattern that is not filtered or texture based, there is a reduction in internal validity, as the stimulus type will have a greater effect on the interpretation of the questions being asked. For example, the use of silhouettes as per Baylis and Driver (1994) is a suitable stimulus for examining figure-ground effects of symmetry type, as the silhouetted image can be perceived as a physical object. However, this imposes a particular perception of the stimulus on the participant, i.e. object based. Conversely the use of letter patterns of linear dot patterns as per Porthos and Ward (2000) impose a serial processing on all symmetry types and again influences the way the participant can interpret the stimuli. Therefore it is important to balance the global processing of a stimulus with the local processing of the stimulus elements. A summary of previous stimulus types used in reflective symmetry detection experiments is presented in Table 5.1.

Table 5.1: Stimuli used in reflective symmetry detection experiments

Author	**Year**	**Stimuli**
Julesz	1971	Dot textures
Carmody et al.	1977	Random shapes
Barlow & Reeves	1979	Dot patterns
Locher & Nodine	1989	Abstract art displays
Wagemans et al.	1991	Dot patterns
Locher & Wagemans	1993	Line orientations
Baylis & Driver	1994	Silhouettes-
Li & Westheimer	1997	Circles and crosses
Dakin & Hess	1997	Gaussian filters
Evans, Wenderoth & Cheng	2000	Biological images
Porthos & Ward	2000	Dot patterns
Scharroo & Leuwenberg	2000	Letters
De Kuijer et al.	2003	Silhouettes
Victor & Conte	2004, 2005	Checkerboard
Mancini, Sally & Gurnsey	2005	Checkerboard

Checkerboard patterns may provide a target stimulus that reduces processing biases at either a global or at a local level. Instead, the interpretation of the stimulus is left up to the participant as the stimulus is not presented serially in a linear fashion and if randomly constructed it is up to the participant to decide whether the stimulus should be regarded as an object or a texture. However, the choice of check size and the proportion of the stimuli that should be occupied by black or white checks may become a confounding factor. This is a major confound if a pattern type appears more salient due to a property other than the one that is being actively manipulated such as the relative grouping of the checks or perceived differences in luminance and contrast.

Arguably the effect of changing the check size of a stimulus can be also considered a change in mean display luminance as it reflects a change in the area of the stimulus that is black. Changes in scale and luminance could have an effect on the information content of a stimulus by creating an attentional bias to either the lighter or darker checks in the pattern. In order to account for this, the checkerboard stimuli need to be counterbalanced. One possible method for examining this could be to look at anti-symmetry. Anti-symmetry can be defined as a symmetrical image where one half the image is the negative of the other (Figure 5.2). In other words the information content in an anti-symmetrical image is the same as that of its symmetrical isomer, however one half is a reflection in negative and therefore of may possess a different luminance profile (Victor & Conte, 2004).

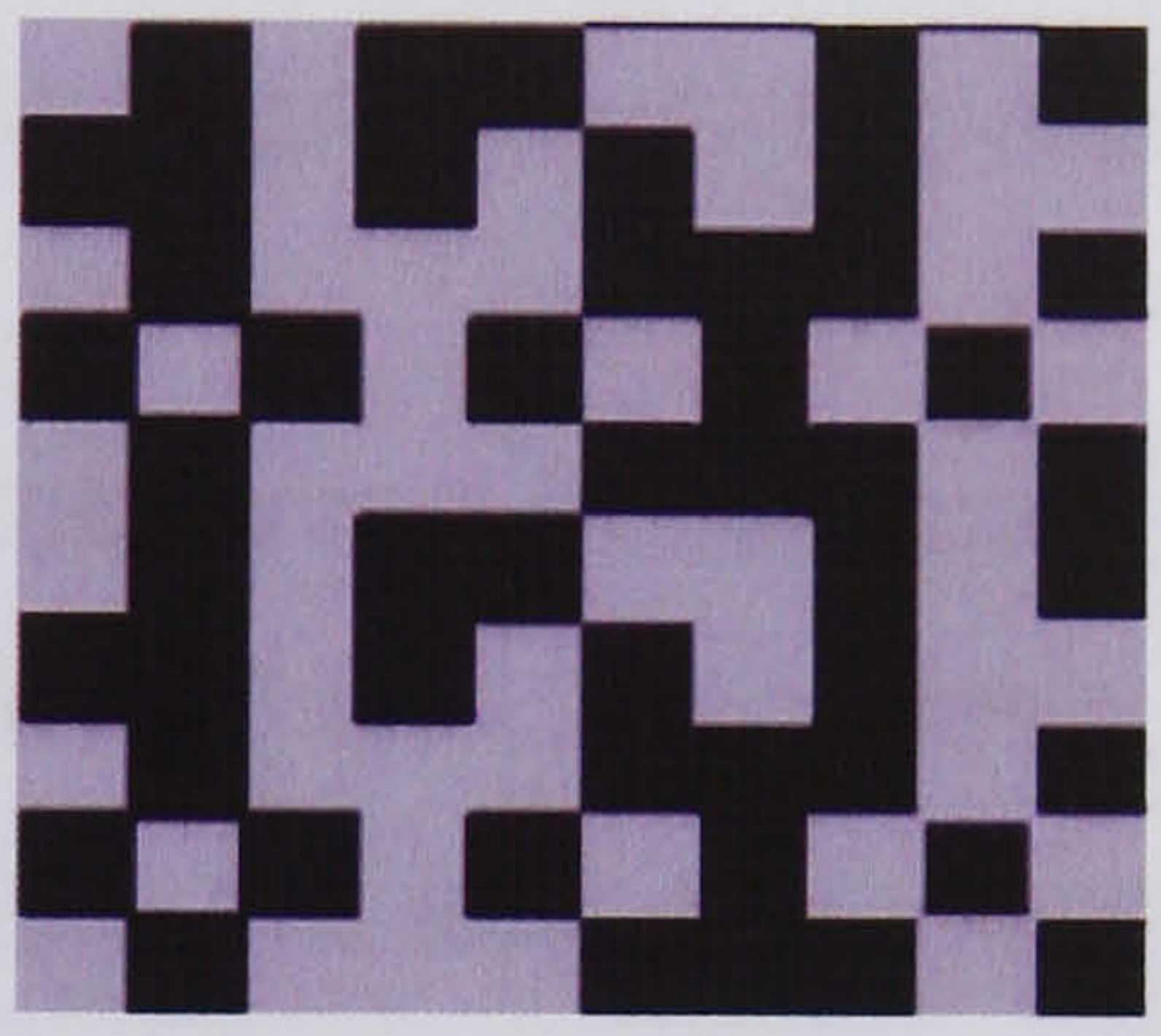


Figure 5.2: Example of anti-symmetry, each half is the negative of the other.

Anti-symmetry has been used to investigate whether reflective symmetry detection is a rapid parallel visual process or a slow serial process (Mancini, Sally & Gurnsey, 2005). Mancini et al. (2005) showed that for normal reflective symmetry, changes in the check size had no effect on how readily a pattern was recognised. However if there is contrasting luminance between the two halves, i.e. the image is presented in anti-symmetry, then an increase in check size improved the detection of the stimulus. This suggests that an increase in luminance can increase detection of certain stimulus types. Mancini et al. (2005) concluded that the differences in detection rates between normal reflective symmetry and anti-symmetry suggest that anti-symmetry is processed in a serial point-by-point manner as opposed to a rapid parallel process as in the normal reflective symmetry condition. As repetition has previously been suggested as being a pattern that is processed serially (Baylis & Driver, 1995), check size and the proportion of black checks are factors that have to be included in a subsequent experimental design investigating differences in the visual processing of different symmetry types.

5.1.4 Outline of the experiments

The following experiments investigated differences between symmetry types in terms of how accurately a target stimulus can be identified under different conditions within a backward masking experiment. The symmetry types studied included repetition, reflection, and patterns that contain a combination of repetition and reflection. Each target and mask stimulus was presented at each of 5 ISIs selected to study the time course of early visual processing of patterns. The aim was to identify whether different pattern types were more readily perceived at different stages of visual processing.

The target patterns were presented in the form of checkerboards so that a variety of other conditions could be manipulated: (1) the number of variants, (2) the number of repeats, (3) the axis of symmetry and (4) the proportion of black checks. The number of variants, i.e. how many variations of an image can be created by reflection or rotation was incorporated into the design as measure of information redundancy within the reflective stimuli. The orientation of the axis of reflection was also incorporated into the design, as this is a recurring theme in studies of symmetry perception (Bornstein, Ferdinandsen & Gross, 1981; Palmer & Hemenway, 1978; Li & Westheimer, 1996; Vauclair, 1983; Wenderoth, 1994). The number of repeats was incorporated into the experimental design as a measure of information redundancy for the repeated stimuli. To account for variations in the amount of black checks within target stimuli, each stimulus was also presented in a negative of itself, i.e. with the black checks and grey checks reversed. By balancing the stimuli in terms of these properties these potential confounds can be eliminated from the final analysis and interpretation of the results.

A final factor incorporated into the trials was that of the Gestalt law of common fate/direction. The stimuli in this case comprised of arrowheads pointing along the diagonal axis of a grid. This was incorporated, as common direction reflects another aspect of patterning in the human face, i.e. the way in which the eyes move. Therefore, it was thought relevant to include this factor into the abstract stimuli condition. Finally, as a result of the two main masking experiments a further experiment into the role of the axis of orientation was conducted to see if there was a perceptual bias towards reflection across the vertical axis.

In the following experiments the dependent variables measured were either the accuracy (d') or the response bias (c) in conditions where signal detection theory was appropriate, or reaction time (ms) and the proportion of correct responses for all other conditions.

5.2 Methods

5.2.1 Design

Participants were randomly presented with a series of patterns that contained (i) random, (ii) reflective symmetry, (iii) repetition or (iv) reflective symmetry and repetition. These pattern types were either constructed out of (a) large or (b) small elements. A within participant design was adopted.

5.2.2 Participants

Sixteen participants, 6 male and 10 female were obtained from an opportunistic sample at the University of Gloucestershire. All participants were offered £5 compensation for their time regardless of the number of trials they completed. All participants were aged between 19 and 40 years old and all had Normal or corrected-to-normal vision. All the participants completed all the trials in the experiment. All participants provided their written informed consent prior to taking part in the experiment and were free to leave the experiment at any time.

5.2.3 Apparatus

The computer apparatus and software used for this experiment was the same as described in the general methodology (Chapter 4; section 4.8).

5.2.4 Stimuli

The stimuli were 10 x 10 or 5 x 5 checkerboard patterns (see Appendix A). The patterns consisted of black squares on a grey checkerboard background. The stimuli represented 4 types of pattern groups (1) random, (2) reflection, (3) repetition, and (4) patterns containing repetition and reflection (see Figure 5.3). The main symmetry stimuli (i.e. pattern groups 2, 3, & 4) were based upon the randomly generated patterns so that there would be no aesthetic bias on the part of the experimenter in the production of the stimuli. To generate the random patterns a random number generator was used, where each number corresponded to a square present on the 10x10 grid. The random patterns were then used to create the various symmetry types either by reflecting the bottom left corner or left half of the image. These basic patterns were presented in all rotations and in negative to counterbalance any luminance biases and orientation bias. In order to counterbalance for subsequent variations in the proportion of black checks, and therefore differences in luminance, each stimulus was also presented as a negative of itself. Each stimulus was presented in all possible rotations in order to control for any perceptual preferences as a result of the axis of symmetry. See Figure 5.3 for examples of the various patterns types (see Appendix A) for all basic patterns used in the experiment).

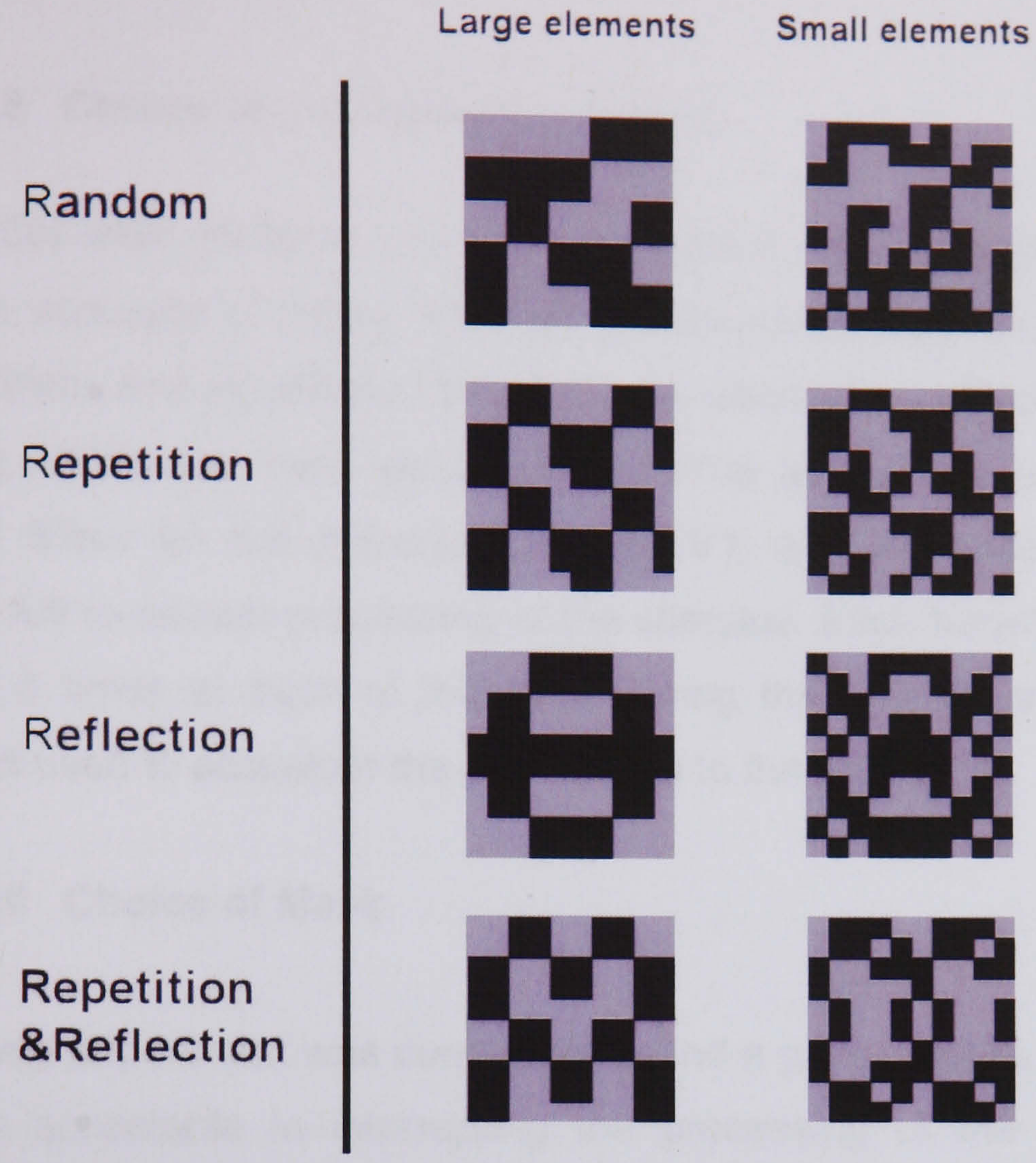


Figure 5.3: Examples of the 4 basic pattern groups, random, repetition, reflection and repetition and reflection. Large elements were based upon a random 5 x 5 grid pattern and the small elements based upon a random 10 x 10 grid pattern.

Furthermore, for each of the four pattern conditions 16 different variations were generated, 8 of these were based on a 10x10 random grid to generate the small elements condition and 8 on a 5x5 random grid to generate the large elements condition. The variation in element size was introduced to manipulate the clustering of black checks, thus providing a comparable measure to the check size condition in the Mancini et al. (2005) experiments. All of the stimuli were presented in the centre of the monitor display at an overall size of 21cm x 21cm. The target area had an eccentricity of 9° from the fixation point. The luminances of the stimuli were 0.51 Lux for the black checks, 0.71 Lux for the grey background, and 0.81 Lux for the white areas of the masking stimulus. The luminance was measured using a Phillip Harris Light Level SensorMeter with a logarithmic range from 1 to 100,000 Lux.

5.2.5 Choice of inter-stimulus interval

All of the ISIs were multiples of the screen refresh rate (approximately 14ms) to increase accuracy of timing. The ISIs selected were (a) 0ms, (b) 14ms, (c) 42ms, (d) 98ms and (e) 208ms. The ISIs were selected to reflect the stages of processing within the early visual system. The key points being between 40ms and 60ms for the activation of area V1, and latencies greater than 150ms for full re-entrant processing of the stimulus. Each target stimulus was presented 5 times at each of the ISIs. During the practice trials an ISI of 500ms was used to accustom the participants to the procedure.

5.2.6 Choice of Mask

A preliminary experiment was conducted to find a pattern mask that would be universally acceptable in interrupting the processing of the checkerboard stimuli, regardless of the check size. Several masks were tried on non-naïve participants and the two strongest masks, i.e. the ones that were most effective at interfering with target recognition, were compared.

Two masks were tested, one containing straight white lines on a black background and one containing swirling white lines on a black background (Figure 5.4). The masks were selected as they contained high contrast diagonal elements that could disrupt the outlines of any underlying checkerboard patterns.

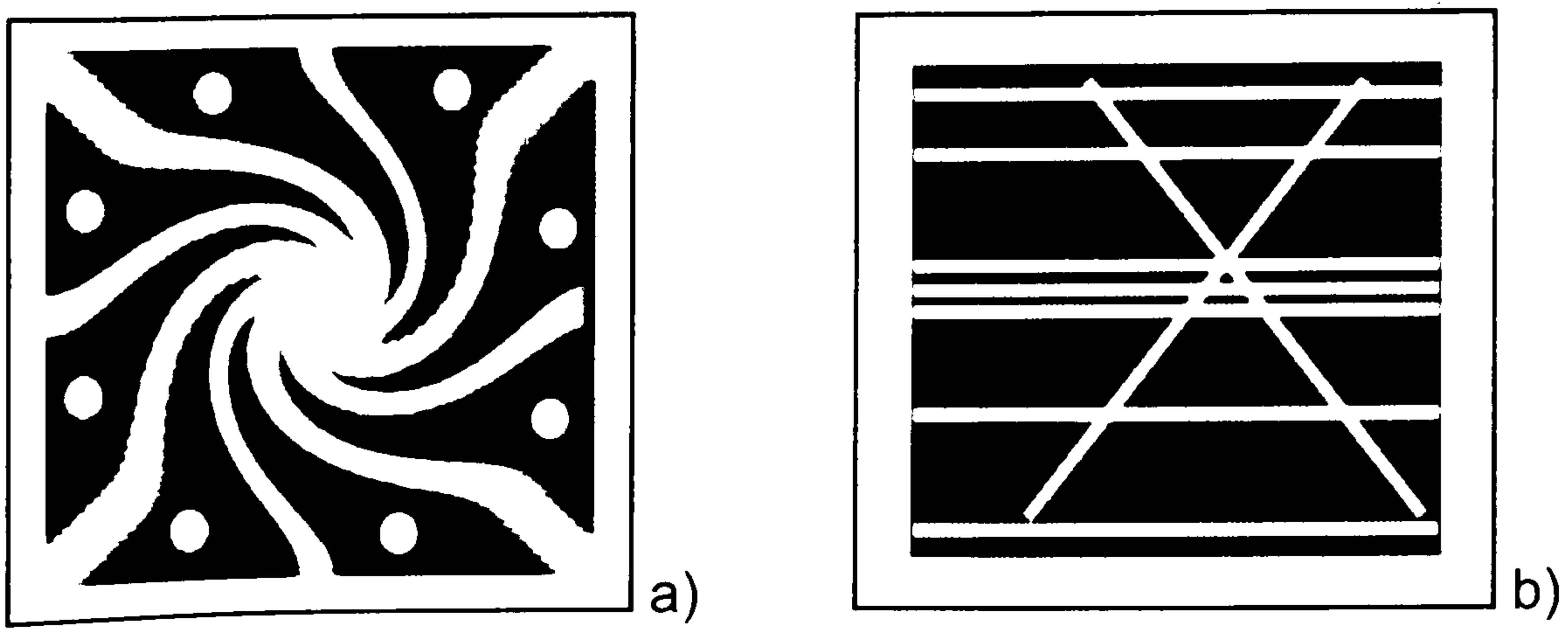


Figure 5.4: The two masks, swirling lines (a) and straight lines (b)

Random stimuli were used in the choice of mask test as these represented the various spatial frequencies of the derived symmetrical patterns and acts as a control in the main masking experiment. The experiments were run on the apparatus described in Chapter 4, section 4.8. Three participants familiar with masking procedures participated in the choice of mask trials. The experiment consisted of 41 trials and the same ISIs outlined in the main methods (Section 5.2.4). The participants were required to identify whether a pattern presented post masking was the same or different to a target pattern presented prior to the mask. The mean proportion of correct responses was examined for all ISIs.

Both of the masks produced masking effects, i.e. poorer performance and a greater number of mistakes, at shorter ISIs. However participant 2 appeared to perform equally well in both conditions. Figure 5.5 shows the overall proportion of correct responses for each participant for each masking condition.

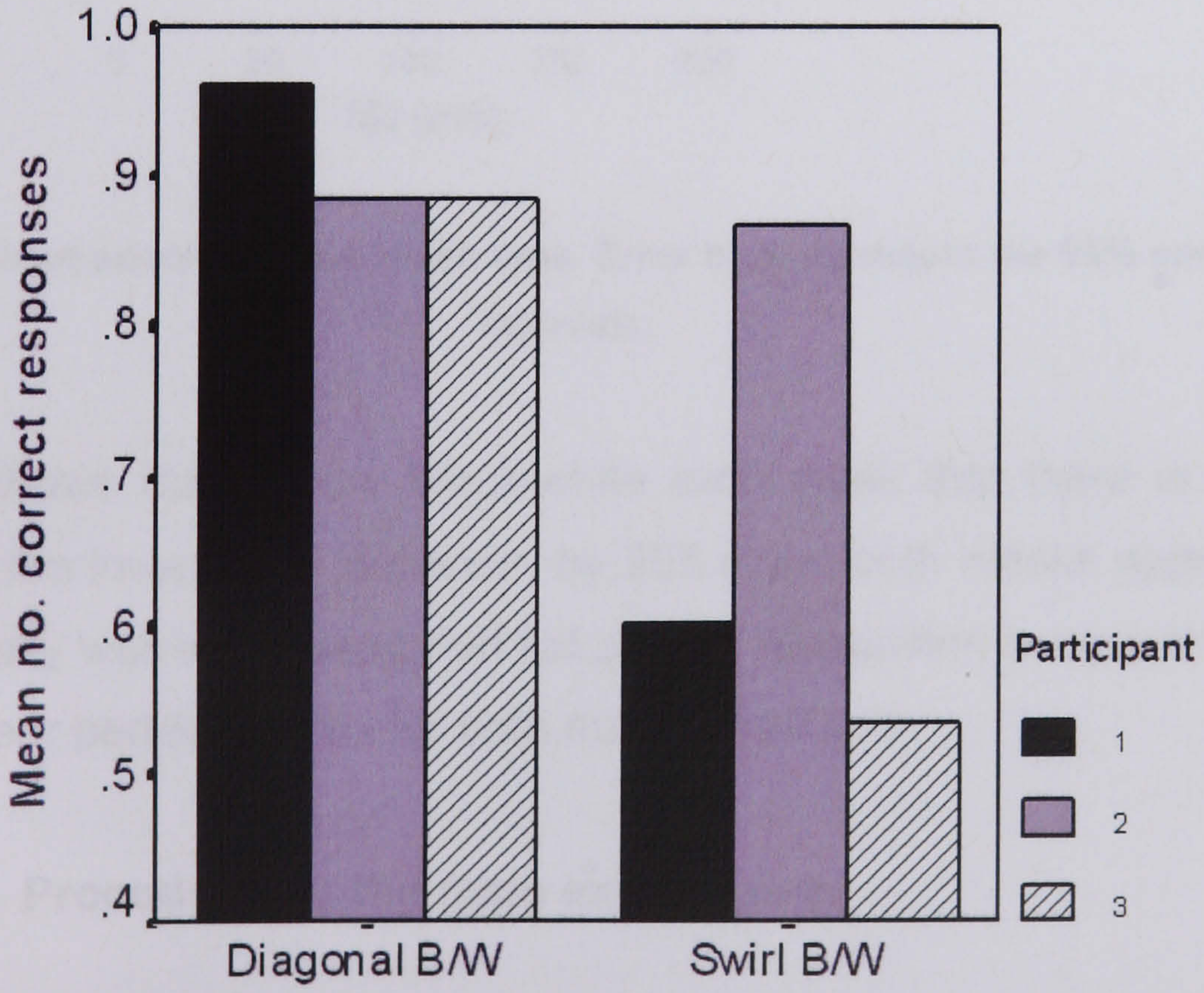


Figure 5.5: Distribution of correct responses. Mean scores for participants 1 to 3 were 0.97, 0.86 and 0.88 respectively for the diagonal black/ white mask. Mean scores for participants 1 to 3 were 0.60, 0.86 and 0.53 respectively for the swirl black/ white mask.

The overall scores for each participant suggest that the swirl mask is the more effective. The mean scores for each mask were compared using a one-way repeated measures randomisation test to account for any autocorrelative effects as a result of the small sample size. It was shown that there was a significant difference in the distribution of scores ($p < 0.001$). The swirl black/ white mask therefore appeared to be significantly more effective at blocking the target stimulus (see Figure 5.6).

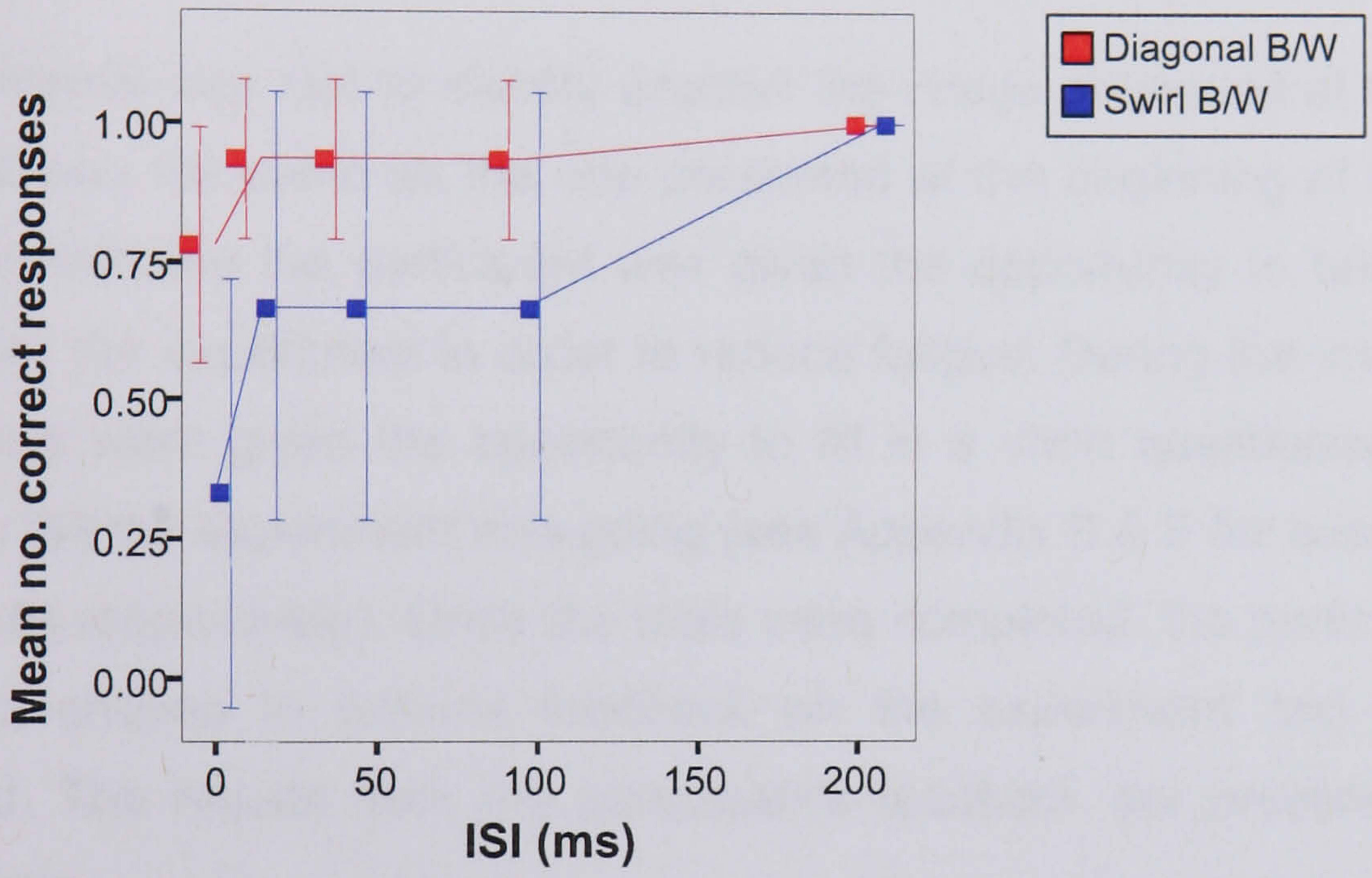


Figure 5.6: Mean score for each mask type. Error bars represent the 95% confidence intervals.

Figure 5.6 shows that for the black/white swirl mask that there is masking occurring at the lower ISIs. However, by 208 msec both masks appear to be working equally well suggesting that full pattern recognition is occurring at this stage with near perfect scores for both mask conditions.

5.2.7 Procedure for the main experiments

The participants were seated in the experimental area. The researcher remained with the participant while they worked through the instructions but left as soon as the practice trials started so as not to distract the participant. In the practice trials the stimuli consisted of random patterns presented with an

ISI of 500 ms. Once the participant had reached 80% accuracy on the practise trials they were able to continue to the main trials, the practise run consisted of 20 trials per cycle, all participants obtained 80% after one cycle of practise trials.

The masking procedure described in the general methodology chapter was used. The experiment took approximately one hour and consisted of 440 main trials. Each condition was presented to the participant 4 times at each ISI. The order of presentation was randomised to minimise priming or cueing effects.

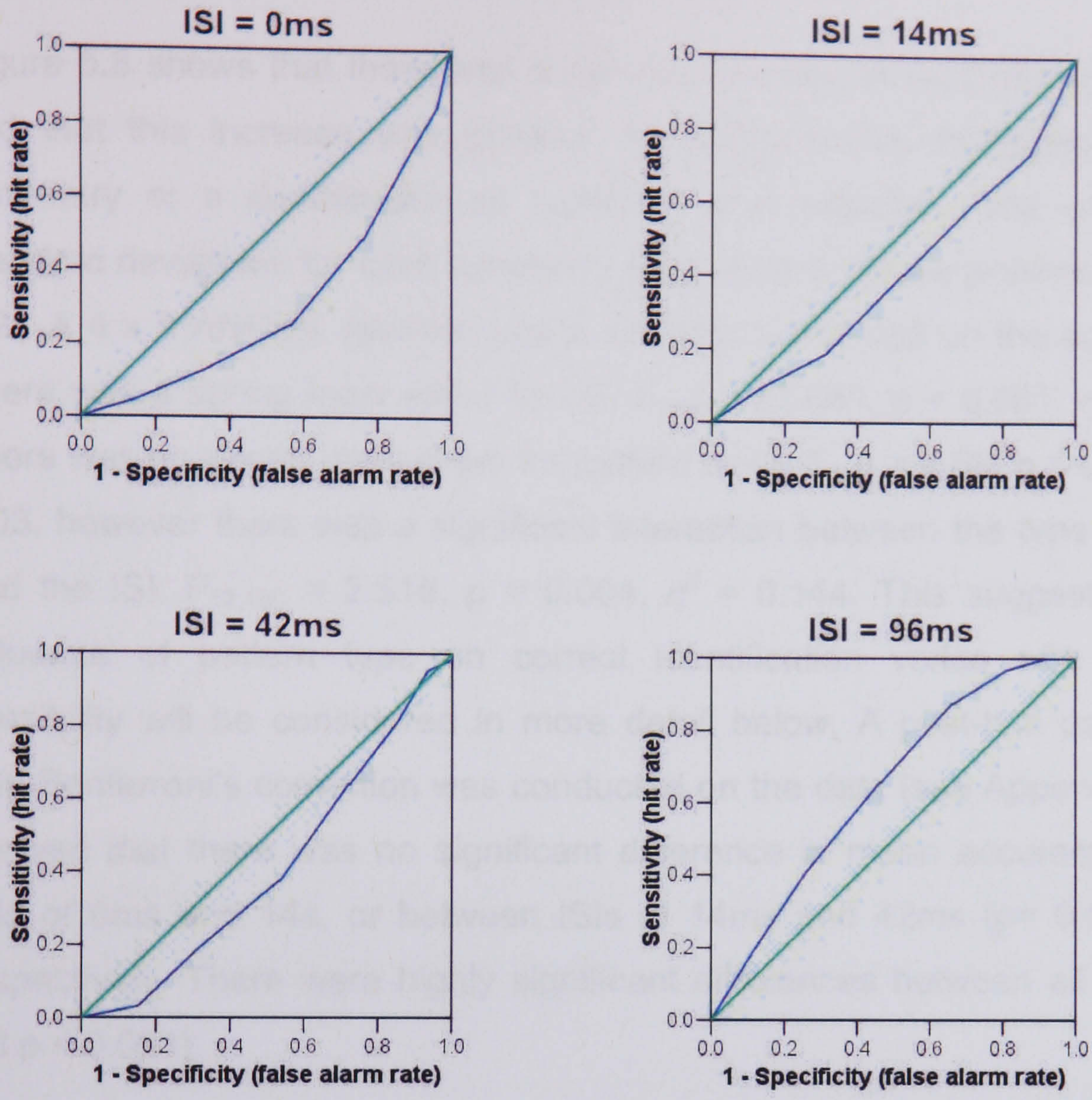
The participant was told to identify whether the image presented at the end of each trial was the same as the one presented at the beginning of each trial. Every ten minutes the participant was given the opportunity to take a short break from the experiment in order to reduce fatigue. During the intervals the participants were given the opportunity to fill in a short questionnaire about how they felt the experiment was going (see Appendix B & E for questionnaire and results respectively). Once the trials were completed, the participant was offered a chance to provide feedback on the experiment and was fully debriefed. The results from the participant's feedback are presented in the appendices.

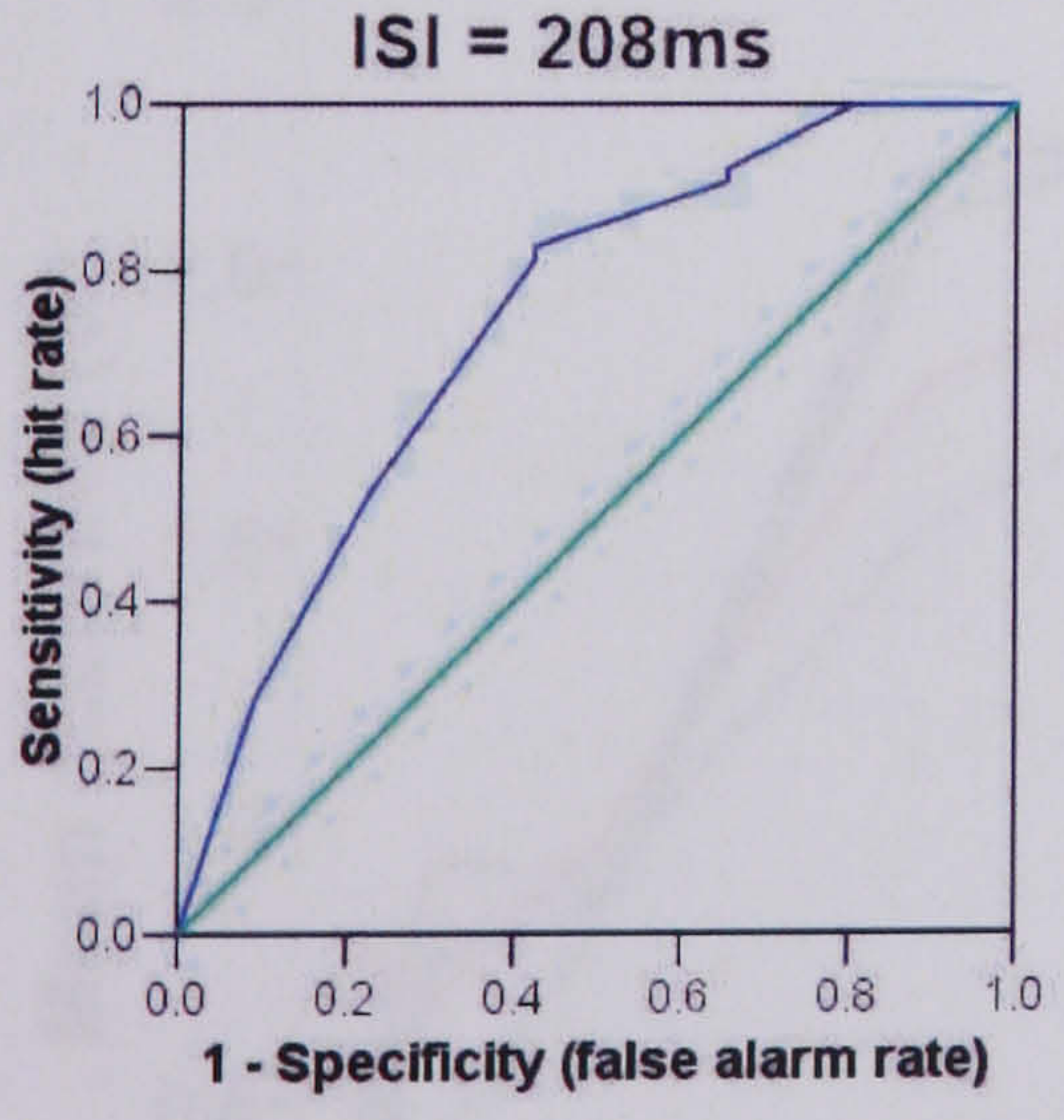
5.3 Results

The dependent variables, accuracy (d'), response bias (c), and mean proportion of correct answers were analysed for differences between pattern types (random, repetition, repetition & reflection, and reflection) and ISIs. The dependent variables were also analysed in terms of the number of variants, repeated elements, axis of reflection and common direction. Prior to examining this the confounding variable of luminance and element size was eliminated by conducting a correlation between the mean group size (number of black checks sharing a border with other black checks) and the mean proportion of correct answers. There was no significant association between the mean group size and accuracy (n=26, r = -0.06, p = 0.770). Therefore check size and clustering could not be regarded as a significant confound in this experiment.

5.3.1 The effect of the mask: accuracy at different processing intervals

The accuracy (d') was recorded for each of the pattern types (i.e. random, repetition, reflection and repetition & reflection) under each of the ISIs. The cumulative accuracy for all pattern types was then used to produce a receiver-operating characteristic (ROC) curve for each of the ISIs. Masking was very pronounced at ISIs of 0ms, as shown in Figure 5.7. This shows that there was a strong bias towards false alarms at this particular interval. The participants were performing significantly worse than chance ($p<0.001$), believing that there had been a change to the target stimulus when none had occurred or that there were no changes when changes had occurred. However, by ISIs of 208ms there was a shift from significantly responding with false alarms towards correctly identifying a change or a no change ($p<0.001$). This suggests that across the ISIs there was an increase in the participant accuracy and that by ISIs of 208ms the participants were sensitive to any changes occurring. This shows that the participants were not guessing throughout the trials and that the accuracy scores are not the result of outliers or chance. However, even at 208ms there is not 100% accuracy and this is reflected in the shape of the ROC curve.





ISI	Area	p
0	0.305	<0.001
14	0.405	0.019
42	0.409	0.024
96	0.64	0.001
208	0.741	<0.001

p = Asymptotic significance

Figure 5.7: Graphs show ROC curves for each ISI, table shows area under curves and asymptotic significance.

5.3.2 Differences between symmetry types

Figure 5.8 shows that there was a general increase in accuracy (d') with ISI and that this increase was greatest for patterns that contained reflective symmetry or a combination of repetition and reflection. The means and standard deviations for each symmetry type at each ISI are presented in table 5.2. A 4 x 5 ANOVA (pattern type x ISI) was conducted on the accuracy d'. There was a strong main effect for ISI, $F_{4,60} = 85.061$, $p < 0.001$, $\eta^2 = 0.850$. There was no strong main effect for pattern alone $F_{3,45} = 4.66$, $p = 0.707$, $\eta^2 < 0.03$, however there was a significant interaction between the type of pattern and the ISI, $F_{12,180} = 2.515$, $p = 0.004$, $\eta^2 = 0.144$. This suggests that the influence of pattern type on correct identification varies with ISI. This possibility will be considered in more detail below. A post-hoc paired t-test with Bonferroni's correction was conducted on the data (see Appendix D) and showed that there was no significant difference in mean accuracy between ISIs of 0ms and 14s, or between ISIs of 14ms and 42ms (p= 0.5 and p=1 respectively. There were highly significant differences between all other ISIs (all $p < 0.001$).

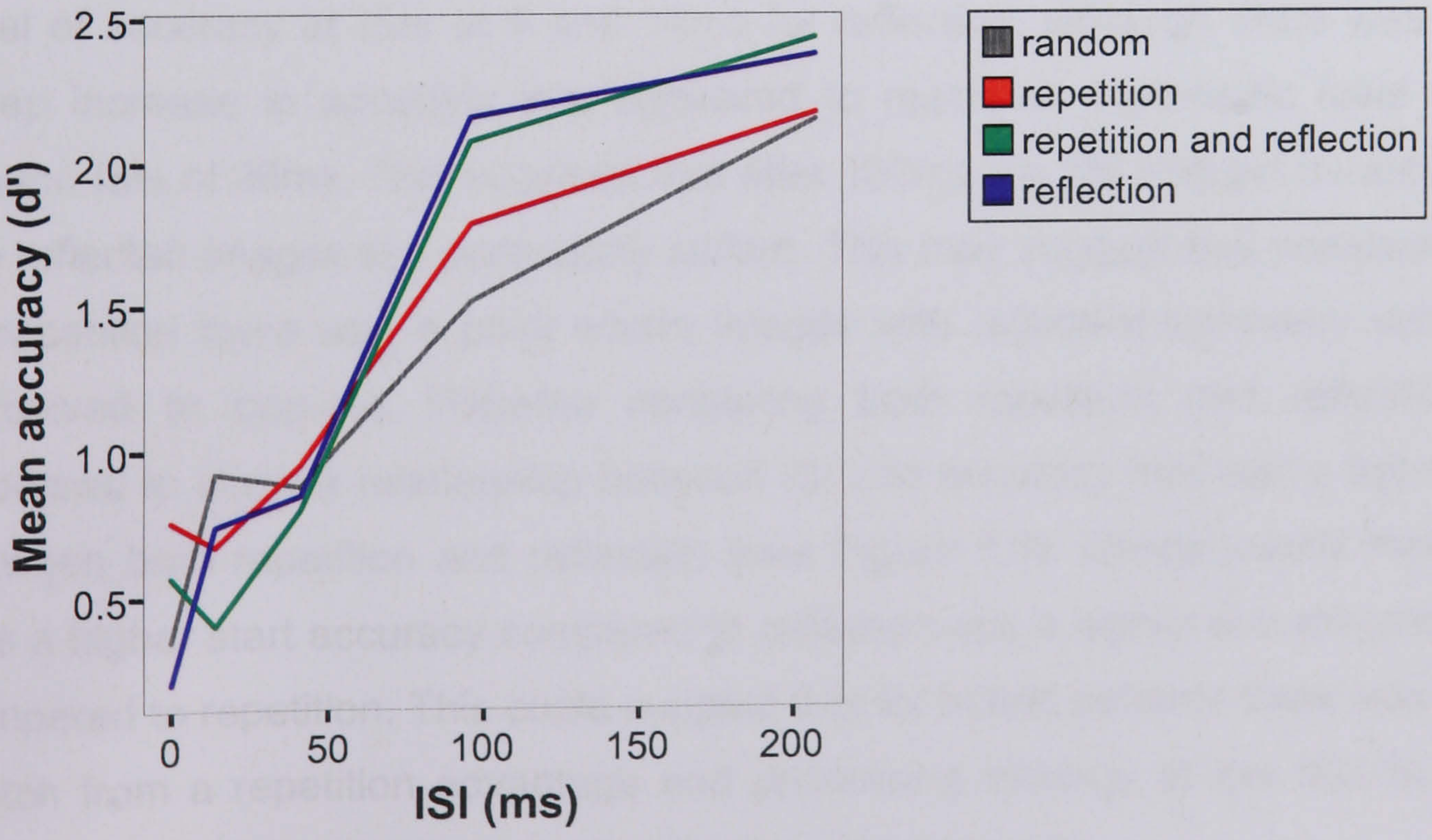


Figure 5.8: The effect of symmetry type on the accuracy of pattern perception

Table 5.2: Means and standard deviations of accuracy (d') for each pattern type at each ISI

ISI		Random	Repetition	Repetition & Reflection	Reflection
0					
	Mean	0.35	0.75	0.56	0.20
	SD	0.61	0.69	0.70	0.54
14					
	Mean	0.92	0.68	0.39	0.74
	SD	0.66	1.00	0.76	0.71
42					
	Mean	0.89	0.96	0.80	0.85
	SD	0.93	0.67	0.80	0.76
96					
	Mean	1.52	1.79	2.08	2.16
	SD	0.59	0.52	0.59	1.05
208					
	Mean	2.15	2.17	2.43	2.38
	SD	0.54	0.68	0.77	0.70

As illustrated in Figure 5.9 and Table 5.2, each pattern type differentially varies with ISI. Random patterns appear to show a predominantly linear increase with an increase in ISI. This could be the result of serial processing of the stimulus. Repetition shows a high start accuracy followed by a slight decline at 14ms and then a largely linear trend in increase. There was a low level of accuracy at ISIs of 0 and 14ms for reflection, although there was a steep increase in accuracy that appeared to reach an asymptotic level at around ISIs of 96ms. This suggests that after 100ms, i.e. ISI + target duration, the reflected images are particularly salient. This may suggest that compared to repetition there was a point where images with reflective symmetry were perceived to pop-out. Patterns containing both repetition and reflection appeared to show a relationship between ISI and accuracy that was a hybrid between both repetition and reflection (see Figure 5.9). Consequently there was a higher start accuracy compared to reflection and a higher end accuracy compared to repetition. This could suggest that for hybrid patterns there was a switch from a repetition advantage and processing strategy at low ISIs to a reflection advantage and processing strategy at higher ISIs.

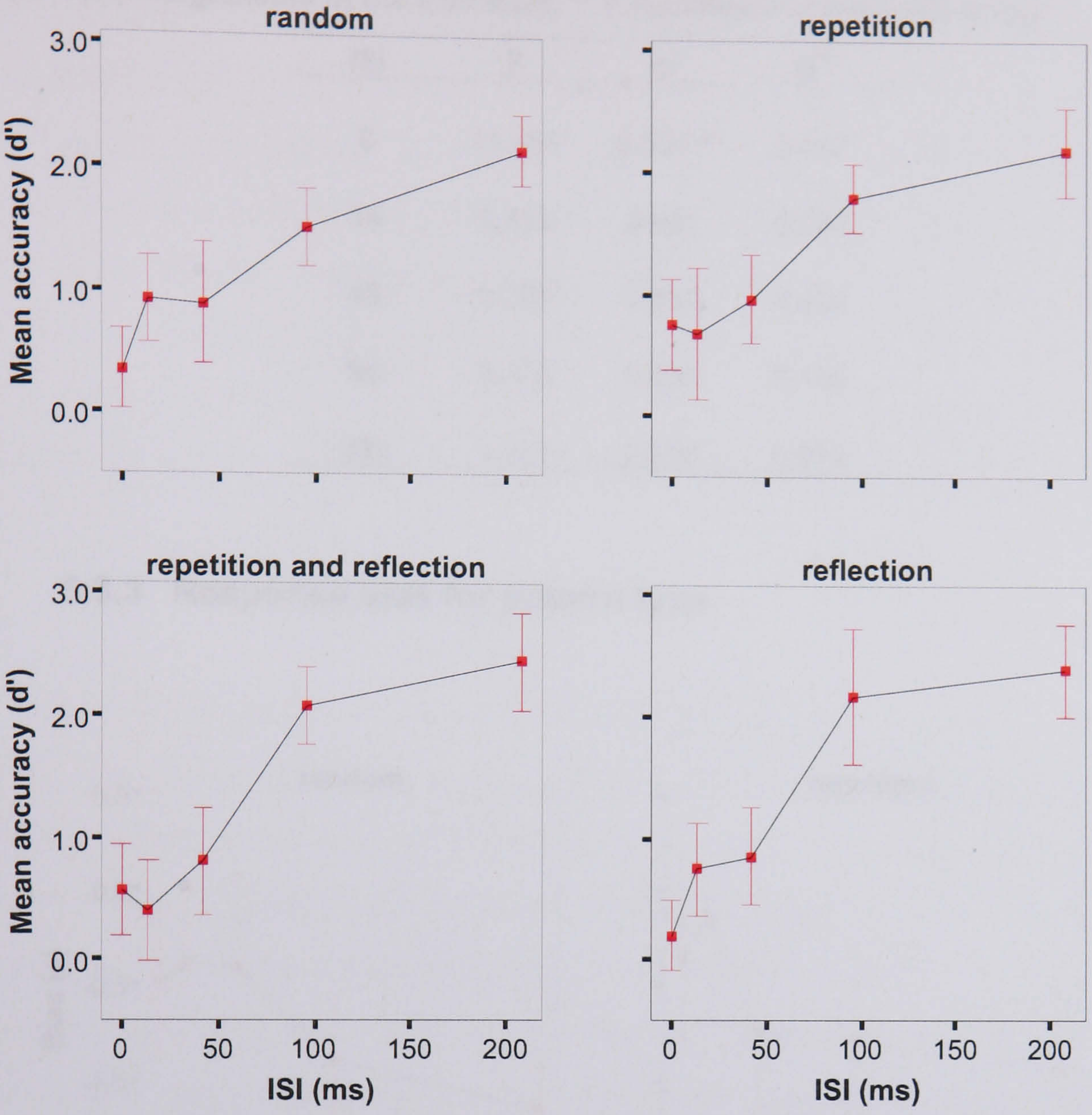


Figure 5.9: The relationship between accuracy and ISI for each of the four pattern types. Error bars represent the 95% confidence intervals.

There was a significant difference in accuracies between repetition and reflection at an ISI of 0ms and a borderline significant difference at 96ms. There was no significant difference in accuracy between repetition and reflection at the other ISIs (see Table 5.3). However as demonstrated in Figure 5.8, there is a trend towards greater accuracy for reflection compared with repetition at higher ISIs (208ms). This suggests that there may be an early perceptual advantage for repetition and a later advantage for reflection.

Table 5.3: Results of one-way within subjects ANOVA between reflection and repetition at each ISI (*= significant at the 0.05 level; ** = significant at the 0.005 level).

ISI	F	*p*	η^2
0	11.631	0.004**	0.437
14	0.053	0.821	0.004
42	0.365	0.555	0.024
96	3.403	0.085	0.185
208	1.172	0.296	0.072

5.3.3 Response bias for pattern type

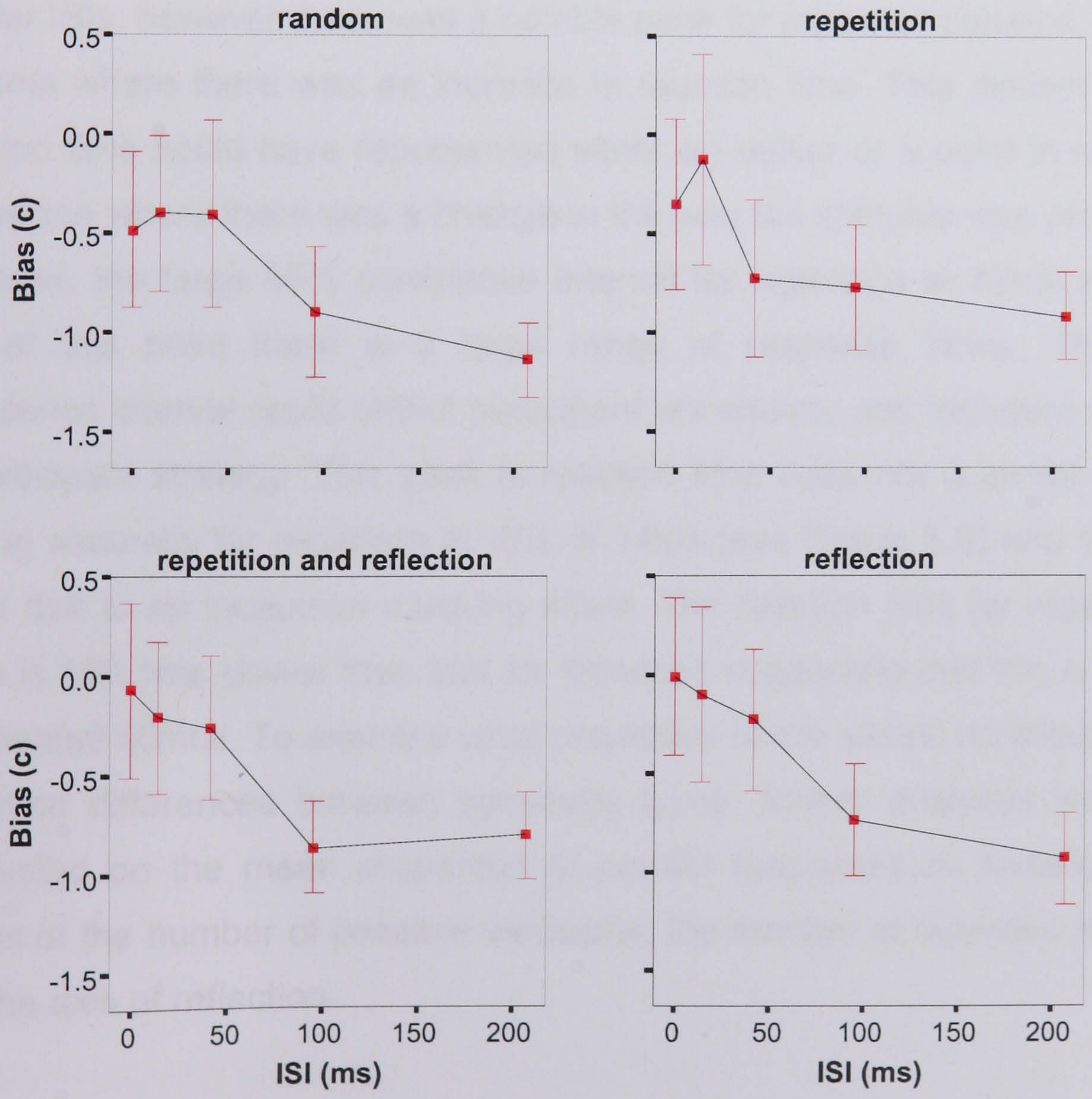


Figure 5.10: The relationship between mean response bias (c) and ISI for each of the four pattern types. Error bars represent the 95% confidence intervals.

The mean response bias, c (see Chapter 4, section 4.9.1), for each pattern type is shown in Figure 5.10. In general the increasing negativity of the values show that as the ISI was increased there was an increase in correct rejection and correct acceptance during the forced choice tasks. However, the response bias for repetition shows a peak at 14ms, suggesting that there is a slight bias towards false alarms, however by 42ms the response bias for repetition appears to level out. The change in response bias appears to be more gradual for the other pattern types. This again suggests that perhaps repetition has a perceptual advantage during brief visual presentations.

5.3.4 Reaction time

As shown in Figure 5.11 there was a slight decline in reaction time with greater ISIs, however there was a notable peak for repeated patterns at an ISI of 42ms where there was an increase in reaction time. This distinct peak in reaction time could have represented either an outlier or a point in repetition perception where there was a change in the way the stimulus was processed. However, the large 95% confidence interval for repetition at 42ms suggests that at this point there is a large range of response times. This large confidence interval could reflect participant uncertainty and therefore a switch in participant strategy. This peak in reaction time does not coincide with the drop in accuracy for repetition at ISIs of 14ms (see Figure 5.9) and therefore is not due to an increased masking effect. The reaction time for repetition at 42ms is 180.1ms slower than that for reflection suggesting that this is specific to repeated stimuli. To examine what properties of the stimuli contribute to the observed differences between symmetry types, further analyses were then conducted on the mean proportion of correct responses to investigate the effects of the number of possible variations, the number of repeated elements and the axis of reflection.

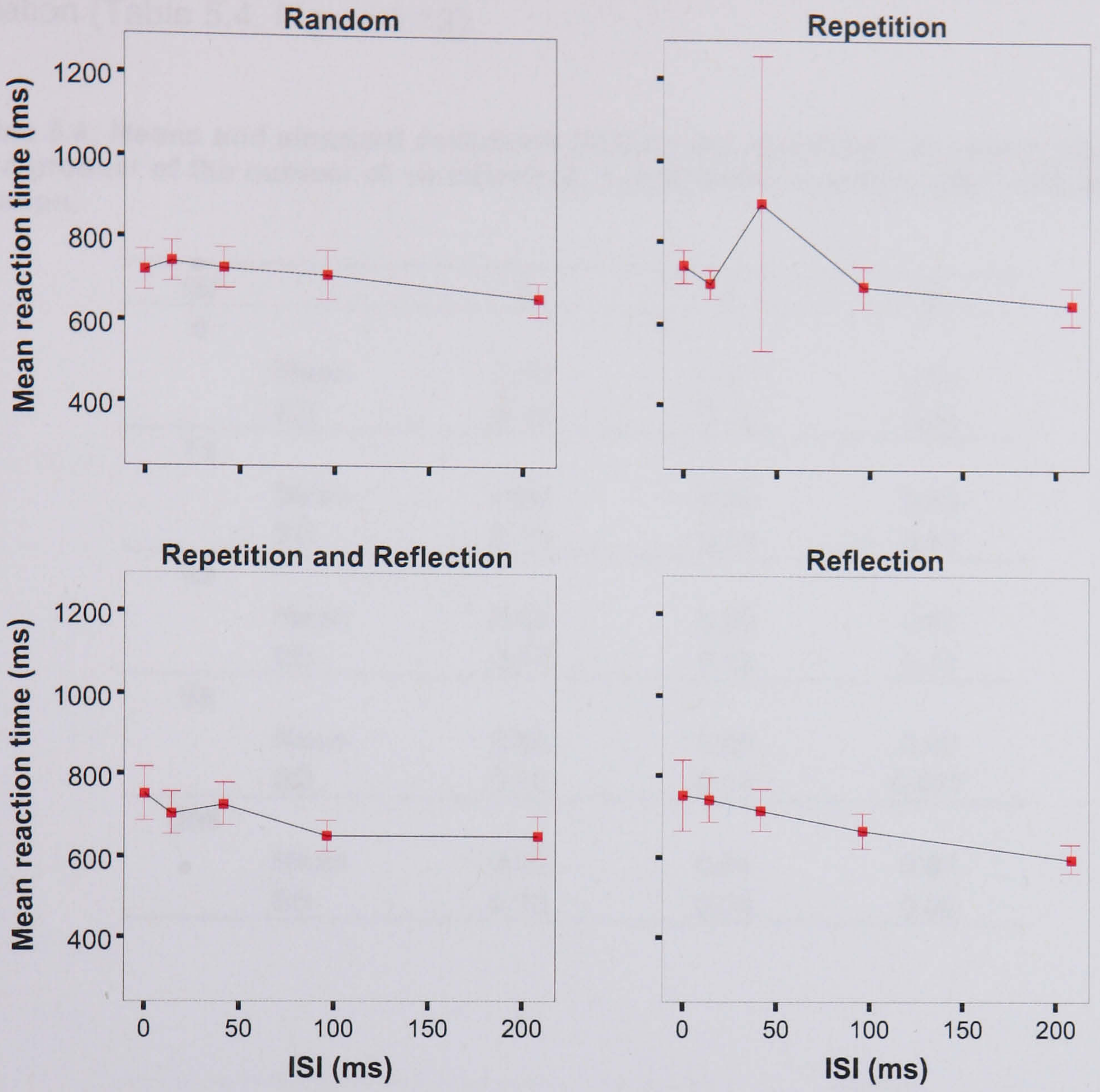


Figure 5.11: The relationship between mean reaction time and ISI for each of the four pattern types. Error bars represent the 95% confidence intervals.

5.3.5 The effect of number of variants on patterns with reflective symmetry

The proportion of correct responses was considered in regard to the number of variants in the pattern. As the stimuli are based upon randomly generated patterns there were no patterns generated via reflection across the vertical and horizontal axis that only possessed one possible variation. Therefore the results presented are for patterns that contain 2, 4 and 8 possible variants after reflection and rotation (see Chapter 1: Figure 1.2 for examples). Figure 5.12 shows the general trend in the mean proportion of correct responses for each of the variant types. There appears to be greater accuracy in responses for patterns that possess only 2 or 4 possible variants after reflection and rotation (Table 5.4, Figure 5.12).

Table 5.4: Means and standard deviations (SD) for the proportion of correct responses as a product of the number of variations (2, 4 or 8) within a pattern after reflection and rotation.

ISI		2	4	8
0				
	Mean	0.56	0.57	0.60
	SD	0.16	0.12	0.09
14				
	Mean	0.64	0.59	0.63
	SD	0.13	0.13	0.12
42				
	Mean	0.68	0.66	0.67
	SD	0.17	0.12	0.13
96				
	Mean	0.88	0.86	0.80
	SD	0.16	0.11	0.077
208				
	Mean	0.90	0.91	0.87
	SD	0.13	0.08	0.06

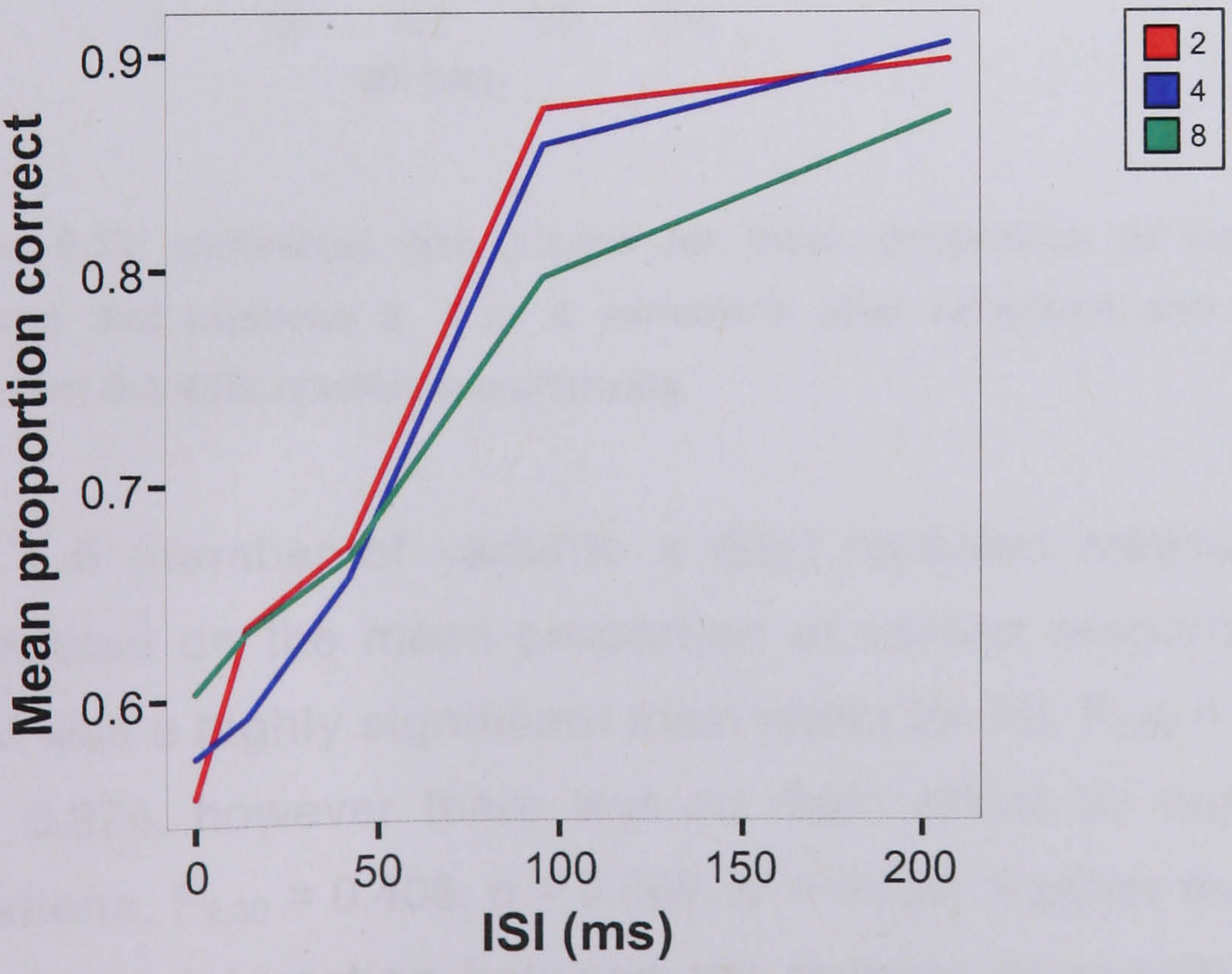


Figure 5.12: The proportion of correct responses for patterns that possess 2, 4 or 8 variations after reflection and rotation.

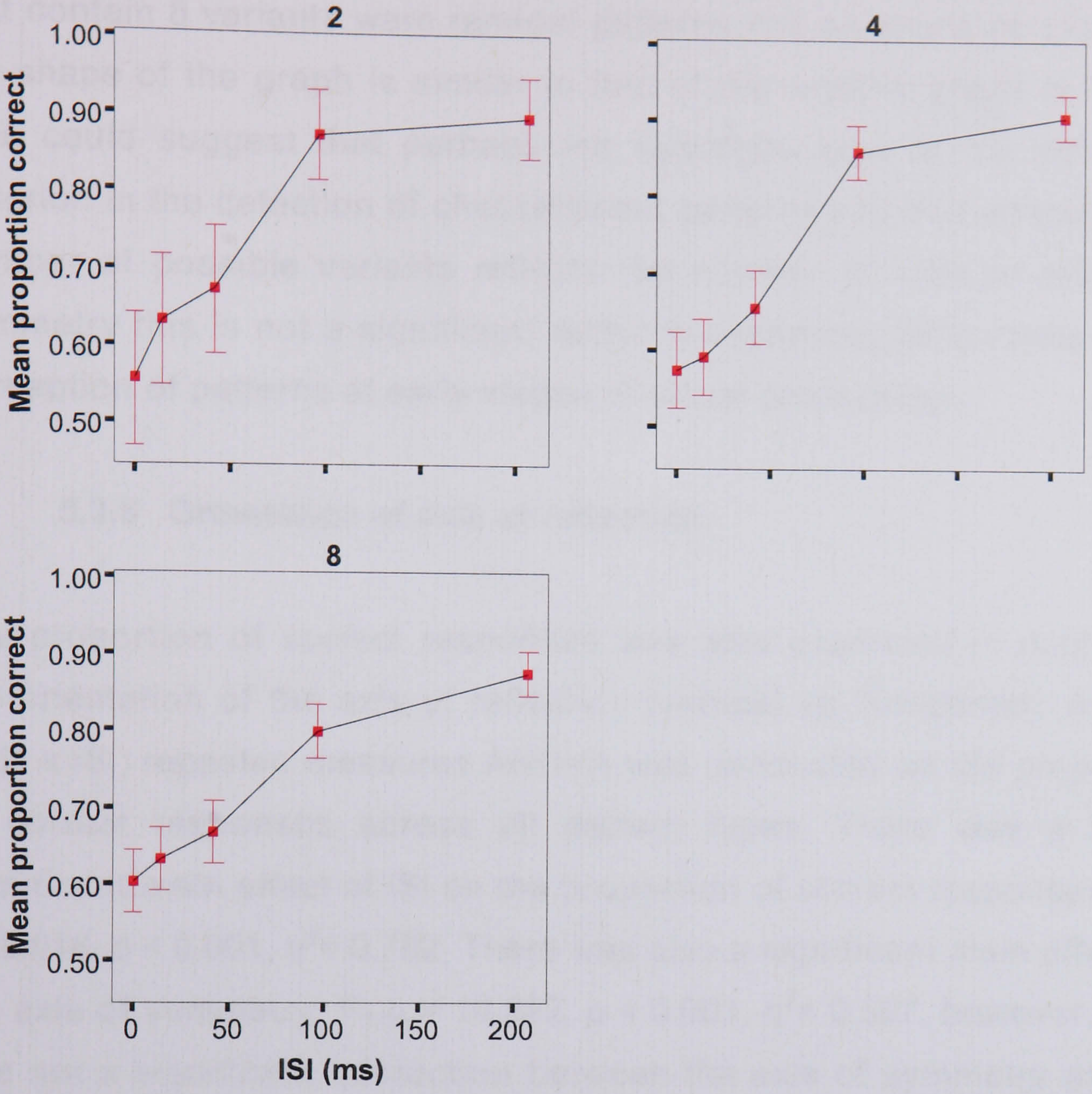


Figure 5.13: Individual line graphs for mean proportion of correct responses for patterns that possess 2, 4 or 8 variations after reflection and rotation. Error bars represent the 95% confidence intervals.

A 3 x 5 (number of variants x ISIs) repeated measures ANOVA was conducted on the mean proportion of correct responses. As expected there was a highly significant main effect for ISI, $F_{4,60} = 70.133$, $p < 0.001$, $\eta^2 = 0.824$, however there was no main effect for number of possible variations, $F_{2,30} = 0.408$, $p = 0.669$, $\eta^2 = 0.026$. Further more, there was no significant interaction between the number of possible variations and the ISI, $F_{8,120} = 1.322$, $p = 0.239$, $\eta^2 = 0.081$. As there was not a significant effect for variations factor no further statistical analysis was carried out. Figure 5.13 shows the individual graphs for each of the three variant conditions. The graphs for patterns that contain 2 or 4 possible variants are very similar to the graph in figure for reflective symmetry. Patterns that contain 8 variants were random patterns and as would be expected the shape of the graph is similar to that of the random graph in figure. This could suggest that perhaps the symmetry type is the important criterion in the detection of checkerboard patterns and that although the number of possible variants reflects the number of lines of reflective symmetry this is not a significant factor in explaining differences in the perception of patterns at early stages of visual processing.

5.3.6 Orientation of axis of reflection

The proportion of correct responses was also examined in respect to the orientation of the axis of reflection (vertical vs. horizontal). A 2 x 5 (axis x ISI) repeated measures ANOVA was conducted on the proportion of correct responses across all pattern types. There was a highly significant main effect of ISI on the proportion of correct responses, $F_{4,60} = 48.016$, $p < 0.001$, $\eta^2 = 0.762$. There was also a significant main effect for the axis of symmetry, $F_{1,15} = 18.882$, $p < 0.001$, $\eta^2 = 0.557$, however, there was not a significant interaction between the axis of symmetry and ISI, $F_{4,60} = 1.916$, $p = 0.119$, $\eta^2 = 0.113$. There appears to be an advantage for reflection across the horizontal axis, this would not be expected as previous studies suggest a bias towards reflection across the vertical axis (Figure 5.14, table 5.5).

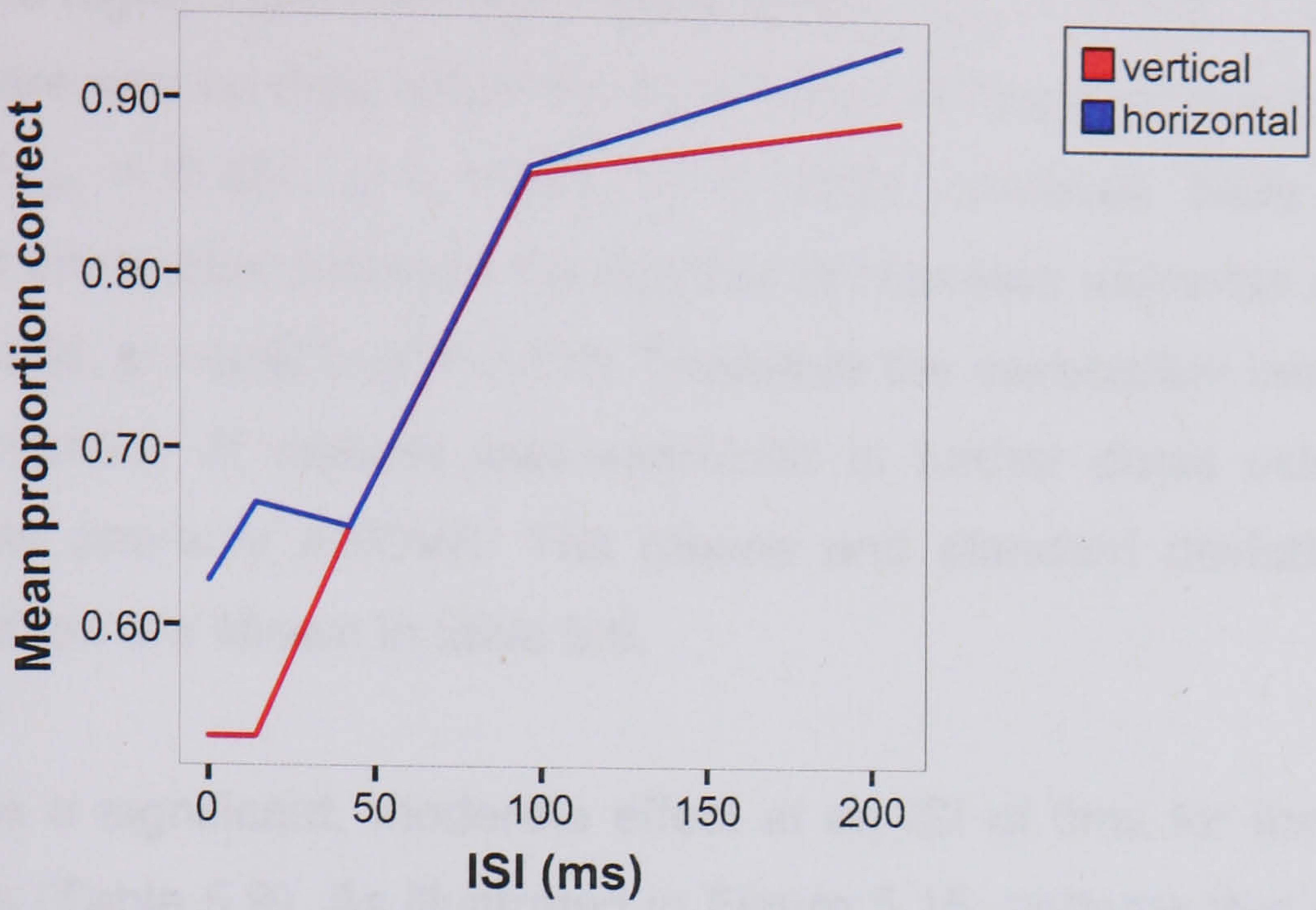


Figure 5.14: The effect of axis of reflection on the proportion of correct scores.

Table 5.7: Means and standard deviations (SD) for accuracy of responses as a product of the orientation of the axis of reflection.

ISI		Horizontal	Vertical
0	Mean	0.62	0.54
	SD	0.49	0.50
14	Mean	0.67	0.54
	SD	0.47	0.50
42	Mean	0.66	0.66
	SD	0.47	0.47
96	Mean	0.86	0.84
	SD	0.34	0.36
208	Mean	0.93	0.87
	SD	0.25	0.33

5.3.7 The effect of number of elements in patterns with repetition

A 3 x 5 (number of repeated elements x ISIs) repeated measures ANOVA was conducted on the mean proportion of correct response. The patterns analysed contained 1 (i.e. random), 2 or 4 repeated elements. As expected there was a highly significant main effect for ISI, $F_{4,60} = 74.097$, $p < 0.001$, $\eta^2 = 0.832$. There was no main effect for the number of repeated elements within a pattern, $F_{2,30} = 0.481$, $p = 0.623$, $\eta^2 = 0.031$, however, there was not a significant interaction between the number of repeated elements and the ISI, $F_{8,120} = 1.855$, $p = 0.073$, $\eta^2 = 0.110$. Therefore the association between score and the number of repeats was examined in further detail using a within participants one-way ANOVA. The means and standard deviations for the correct scores are shown in table 5.6.

There was a significant, moderate effect at an ISI of 0ms for the number of repetitions (Table 5.9). As illustrated in Figure 5.15, patterns that contained 4 repeated elements were more readily perceived than those with 1 and 2 elements respectively. This effect for the number of repeated elements might only be influential at early stages of visual processing as there were no significant differences between the number of repeated elements at ISIs of 14ms, 42ms and 208ms (see Table 5.7). However there was a significant difference reported at 96ms.

Table 5.6: Means and standard deviations for patterns containing 1, 2 or 4 repeated elements at each ISI.

ISI		1	2	4
0				
	Mean	0.55	0.60	0.64
	SD	0.087	0.13	0.12
14				
	Mean	0.63	0.66	0.63
	SD	0.11	0.15	0.17
42				
	Mean	0.66	0.65	0.66
	SD	0.13	0.15	0.12
96				
	Mean	0.81	0.87	0.82
	SD	0.11	0.08	0.08
208				
	Mean	0.89	0.91	0.88
	SD	0.07	0.10	0.09

Table 5.7: Results of one-way within subjects ANOVA between different numbers of repeated elements at each ISI (*= significant at the 0.05 level; ** = significant at the 0.005 level).

ISI	df	F	*p*	*η*
0	2,30	3.517	0.042*	0.190
14	2,30	0.794	0.461	0.050
42	2,30	0.072	0.930	0.005
96	2,30	6.641	0.004**	0.307
208	2,30	0.793	0.462	0.050

Patterns that contain 2 repeated elements appear to be more salient at ISIs of 96ms and 208ms than those that contain 4 repeated elements (Figures 5.15 & 5.16). This could reflect a serial processing of large numbers of repeated elements.

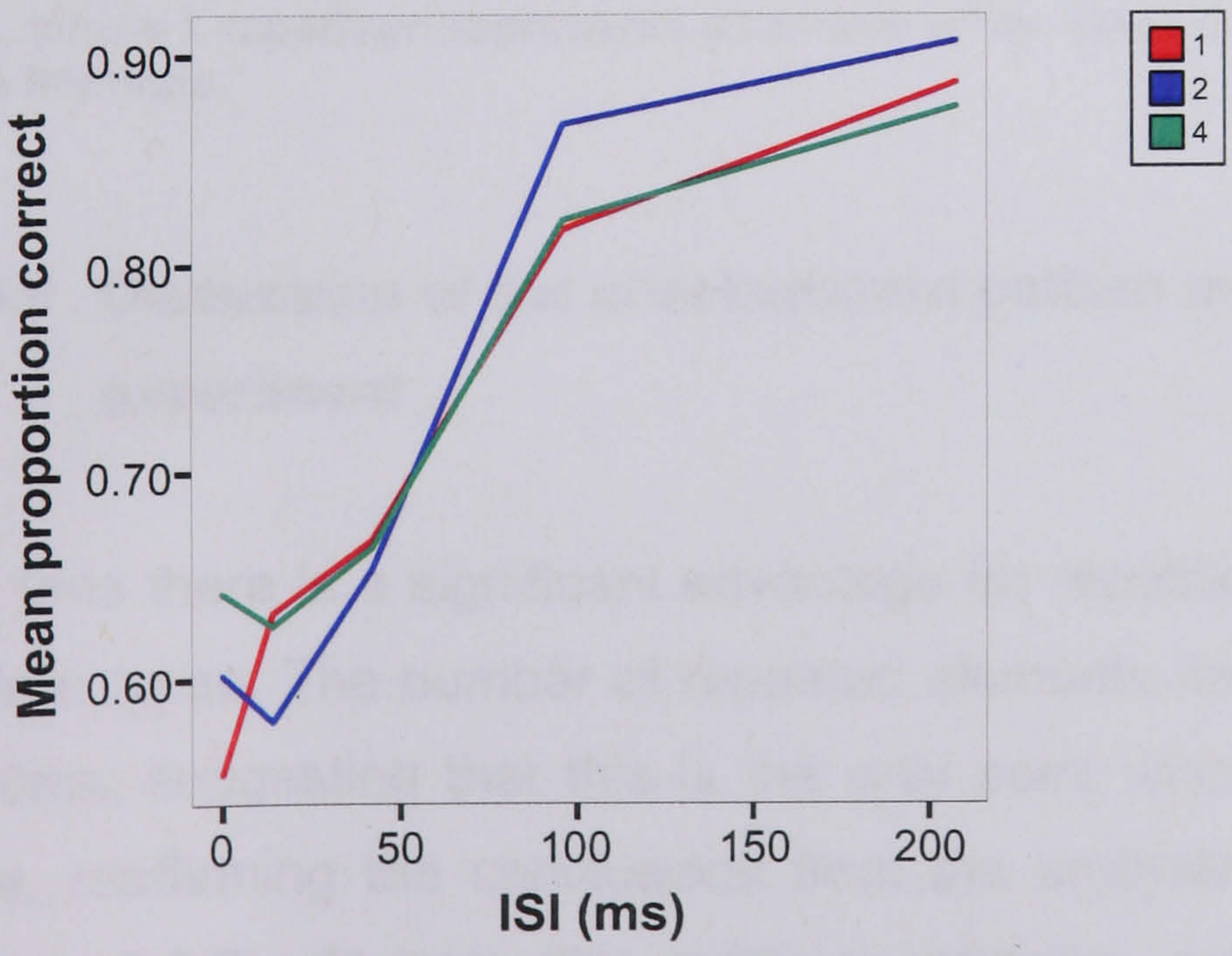


Figure 5.15: The mean proportion of correct responses for number of repetitions where 1 repetition represents a random image.

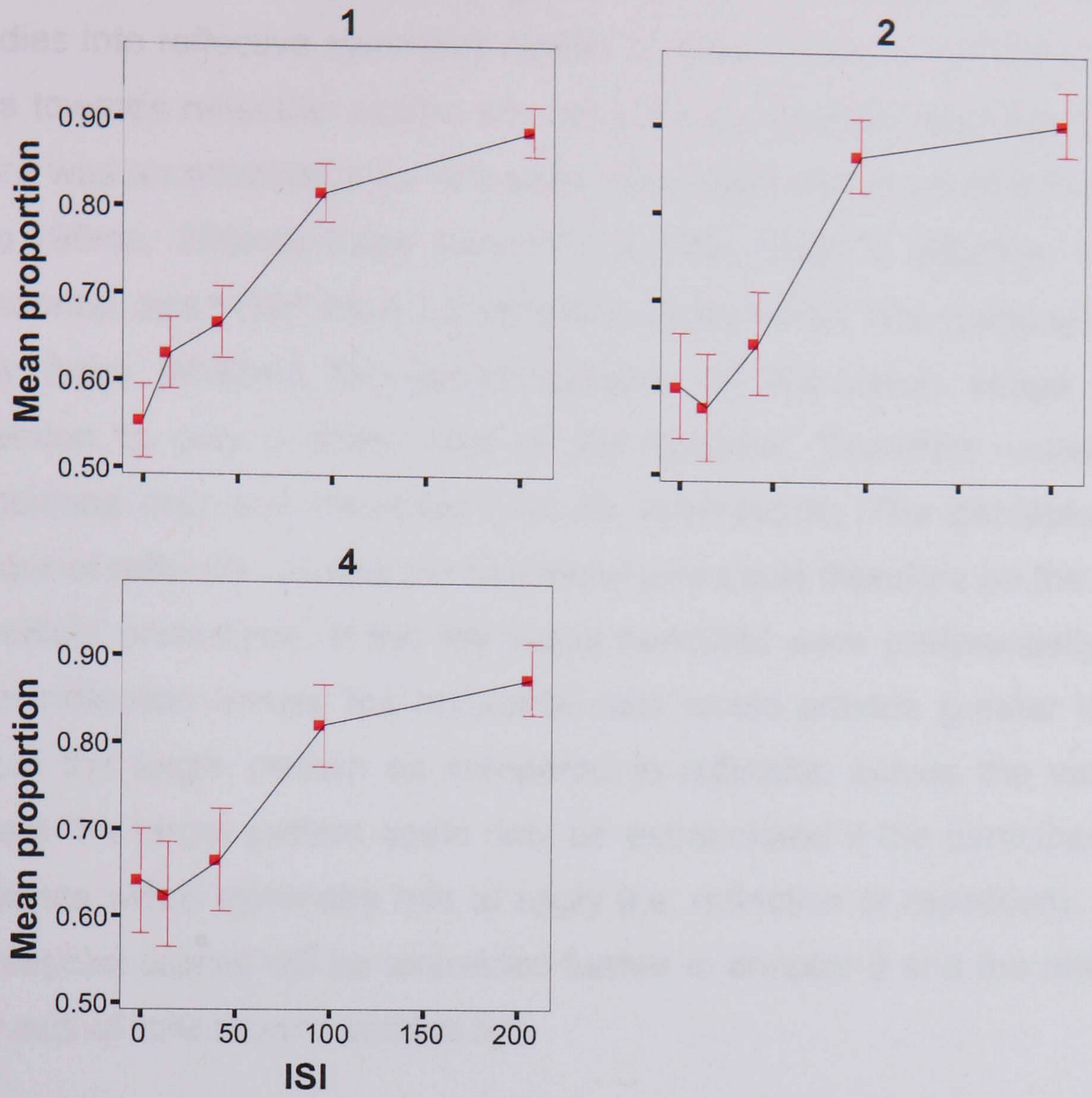


Figure 5.16: The mean number of correct responses for patterns that possess 1, 2 or 4 repetitions, where 1 repetition represents a random array. Error bars represent the 95% confidence intervals.

5.3.8 Discussion of the checkerboard pattern masking experiment

At ISIs of 0ms there is a significant advantage for repetition compared to the other pattern types. The number of repeated elements only had a significant effect at 0ms, suggesting that this is the only point when repetition has an advantage, reaffirming the conclusions from the analysis of symmetry type (see section 5.3.2). At later ISIs (>96ms) reflection appears to have the perceptual advantage. This later bias towards reflection over repetition could be the result of top-down processing effects. Once the stimulus has been detected by area V1 at around 60ms, then top-down processing can provide rapid classification of the stimuli. However, despite greater accuracy for reflection at these higher ISIs the results did not match those of previous studies into reflective symmetry (Dakin & Hess, 1998) in that there was not a bias towards reflection across the vertical axis. At lower ISIs (0ms and14ms) there was an advantage for reflection across the horizontal axis and at higher ISIs (96ms, 208ms) there was also a bias towards reflection across the horizontal axis. The short presentation times within the masking procedure may have inhibited the accommodation of the target image narrowing attention to only a small area of the stimulus. Therefore under masking conditions only one hemifield may be attended to. The perceptual bias in favour of reflection across the horizontal axis could therefore be the result of a hemifield preference. If the left visual hemifield were preferentially attended then reflection across the horizontal axis would provide greater information about the target pattern as compared to reflection across the vertical axis, where the target pattern could only be extrapolated if the participant knew in advance which symmetry rule to apply (i.e. reflection or repetition). Hemifield perceptual biases will be examined further in chapter 8 and the orientation of the axis of reflection in section 5.5.

A supplementary experiment using checkerboard stimuli and the same methodology, as outlined in section 5.2, was conducted to investigate the effect of the Gestalt law of common direction (or common fate). The following experiment was designed to see if there was a difference in saliency between patterns with elements that share common fate or those that do not. This might be important as in everyday life patterns are not always stationary and can exhibit directional properties, e.g. the eyes.

5.4 Common direction

In addition to the 4 pattern type conditions a non-random stimulus was used to examine the Gestalt law of common direction. This was introduced as in the ecologically valid face stimuli the eyes can be perceived as exhibiting common direction in terms of movement.

5.4.1 Participants

Sixteen participants, 6 male and 10 female were obtained from an opportunistic sample at the University of Gloucestershire. The participants were recruited to take part in a variation of the experiment described in section 5.2, where all stimuli were presented on a backing grid (with noise condition), the common direction stimuli were incorporated into this set of trials (See appendix A). All participants were offered £5 compensation for their time regardless of the number of trials they completed. All participants were aged between 19 and 40 years old all and had normal or corrected-to-normal vision. All the participants completed all the trials in the experiment. All participants provided their written informed consent prior to taking part in the experiment and were free to leave the experiment at any time.

5.4.2 Apparatus

The apparatus was the same as in the previous masking experiments (see section 5.).

5.4.3 Stimuli

The stimuli consisted of a series of arrowheads either pointing in a common direction or not pointing in a common direction (see Figure 5.20). The common direction and non-common direction patterns were also presented in reflection to switch the direction the arrowheads were pointing. Both the common direction and non-common direction patterns exhibit repetition and reflection. These stimuli were incorporated into the trials of a "with noise" pattern masking experiment (the "with noise" pattern masking experiment is summarised in Appendix F).

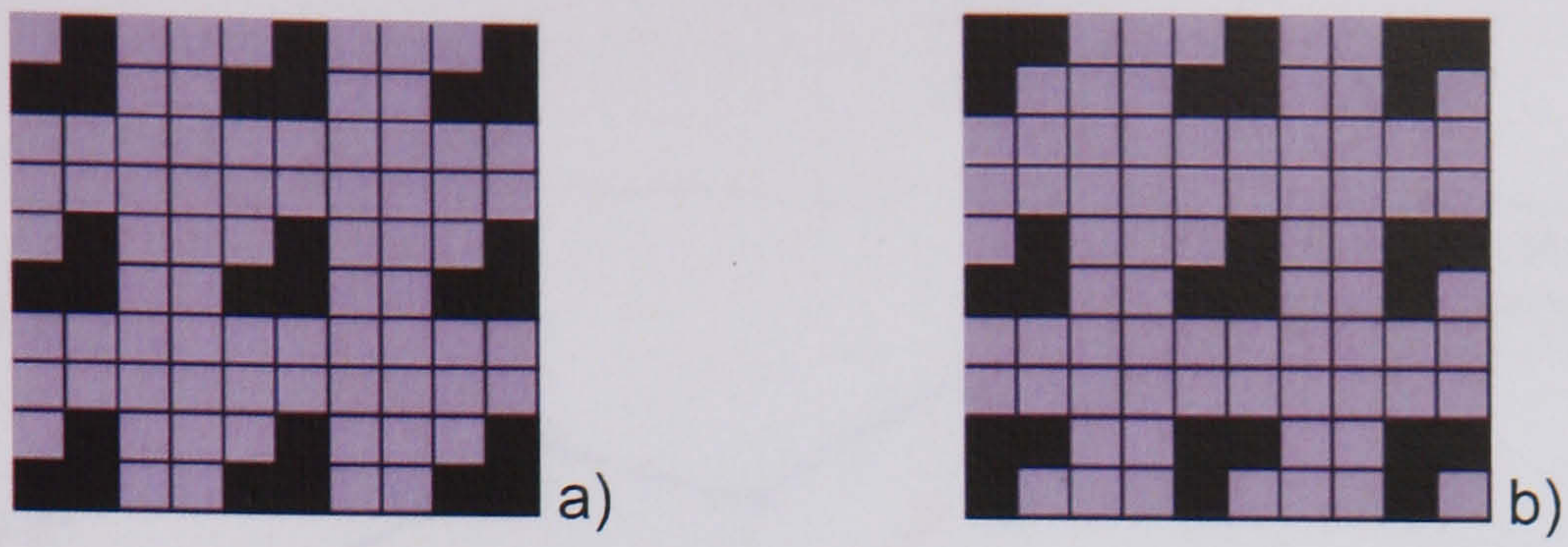


Figure 5.17: Examples of arrowhead stimuli: a) arrows pointing in a common direction and b) pointing in different directions, i.e. non-common direction.

5.4.4 Procedure

The procedure was the same as in section 5.2, except for changes to the ISIs. The ISIs used in this set of trials were (1) 0ms, (2) 14ms, (3) 28ms, (4) 42ms and (5) 56ms. These ISIs were selected to investigate the interruption of early visual processing prior to higher re-entrant processes. Each of the patterns was presented 4 times at each ISI. Each participant undertook 80 common/ non-common direction trials.

5.4.5 Results for common direction

A 2 x 5 (common/ no common direction x ISI) within-participants repeated measures ANOVA was conducted on the mean proportion of correct responses. The results show that there is a significant difference between the result for arrowheads that share common direction and those that do not, $F_{1,14} = 11.452$ $p = 0.004$ $\eta^2 = 0.450$. Table 5.8 shows the means and standard deviations for the two conditions at each of the ISIs. Figure 5.18 shows that there is a trend towards greater accuracy in responses towards stimuli that possess common direction. However at an ISI of 42ms there appear to be a slight reduction in accuracy. This could reflect the suggested change in processing strategy that was suggested for repeated stimuli.

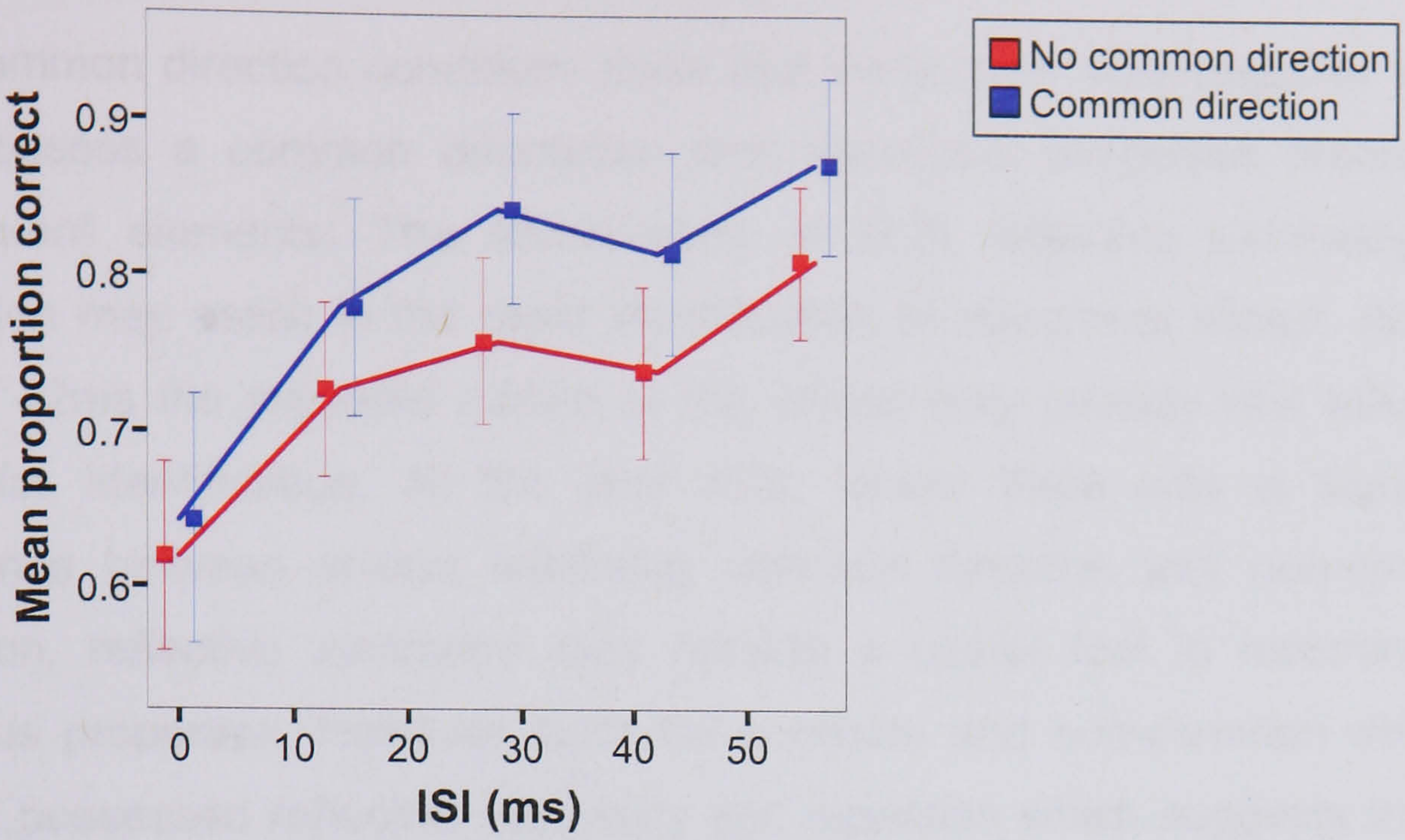


Figure 5.18: The mean proportion of correct responses for patterns exhibitng "common direction" or "no common direction". Error bars represent 95% confidence intervals.

Table 5.8: Means and standard deviations (SD) for the proportion of correct responses to the 2 conditions, common direction and no common direction.

ISI	Condition	Mean	SD
0	Common direction	0.64	0.48
	No common direction	0.61	0.49
14	Common direction	0.78	0.42
	No common direction	0.77	0.42
28	Common direction	0.84	0.37
	No common direction	0.76	0.43
42	Common direction	0.81	0.39
	No common direction	0.71	0.45
56	Common direction	0.87	0.34
	No common direction	0.82	0.38

5.4.6 Discussion of "common direction" conditions

The common direction conditions show that there is an advantage for stimuli that possess a common orientation and directional properties among the constituent elements. The combination of both reflective symmetry and repetition may assist in the rapid identification of directional stimuli. At early ISIs < 42ms the repeated nature of the stimuli may provide vital reference cues for identification. At the later ISIs, where there was a significant difference between arrows exhibiting common direction and non-common direction, reflective symmetry may provide a useful tool in matching the stimulus properties. However, both the common and non-common direction stimuli possessed reflective symmetry and repetition which suggests that the differences between the two in terms of the proportion of correct responses is probably due to the directional properties of the stimulus.

Further to the symmetry pattern masking experiments a second masking experiment was carried out to investigate further the bias towards perception of change across the horizontal axis of reflection (see section 5.3.6) as opposed to the vertical axis of reflection that is frequently cited in the literature (Dakin & Herbert, 1998; Dakin & Hess, 1997; Gurnsey, Herbert & Kenemy, 1998).

5.5 Axis of reflection experiment

In section 5.2, reflection across the horizontal axis was identified as being more salient and this was suggested as possibly being due to insufficient time, within the masking procedures, for participants to accommodate the entire scene resulting in a possible hemifield bias. In previous studies reflected patterns have been identified as being more salient if the pattern elements are presented at close proximity to the axis of reflection (Julesz, 1971; Bruce & Morgan, 1975; Jenkins, 1982). The following experiment aims to investigate the effect of the proximity of a pair of reflected dots and the orientation of the reflected axis on the correct detection of distance within a masking experiment. The dependent variable was the mean proportion of correct matches made between the target and response stimuli.

5.5.1 Participants

Fifteen participants with no prior experience of backward masking experiments were recruited from the University campus. Participants were offered £5 cash for taking part. There were 7 male and 8 female participants all participants were over 18 years old. All the participants completed all of the trials. There were 120 trials in total excluding practice trials.

Prior to the experiment the participants were asked if they suffered from migraines or any photosensitive illness as the experiment required staring at a computer screen for lengthy periods of time. All participants were happy with the procedure and signed the consent form.

5.5.2 Apparatus

The apparatus was the same as in the previous masking experiments (see section 5.).

5.5.3 Stimuli

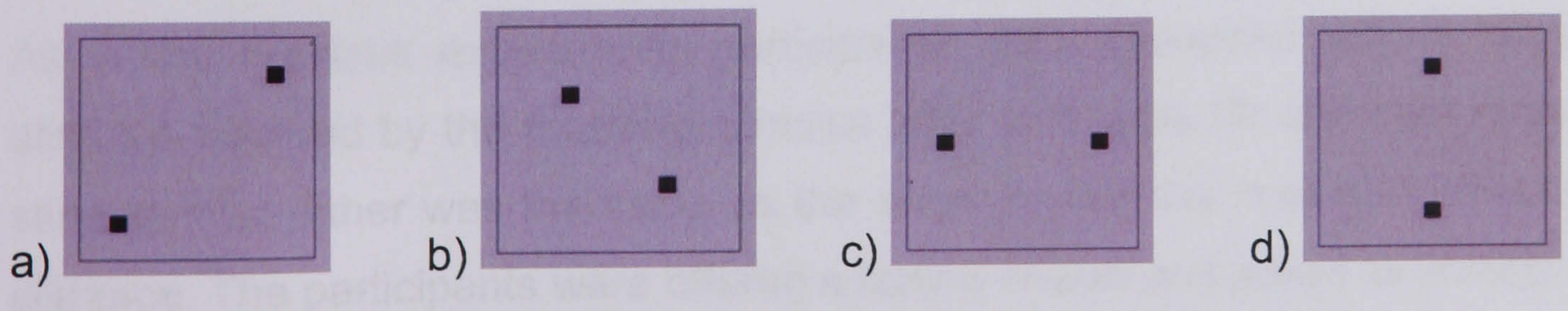


Figure 5.19: Examples of target stimuli: In (a) and (b) the dots are reflected across the diagonal axis, in (c) the dots are reflected across the vertical axis and in (d) the dots are reflected across the horizontal axis

The stimulus displays consisted of dots arranged at varying distance from a central axis. The dots were orientated across either the vertical, horizontal or diagonal axis and reflected across a central line of symmetry (see Figure 5.19). The stimuli provide information about the distance from the line of reflection and the orientation across the field of vision. The stimuli were presented at a size of 21cm x 21cm on the monitor screen. The dots were presented at four distances: 1.5 cm (near condition), 6.5cm (mid-to-near condition), 12cm (mid-to-far condition), and 17cm (far condition). The dots were reflected either across the horizontal, vertical or one of the diagonal axes. A masking pattern was selected that covered all the axes of the displays (see Figure 5.20).

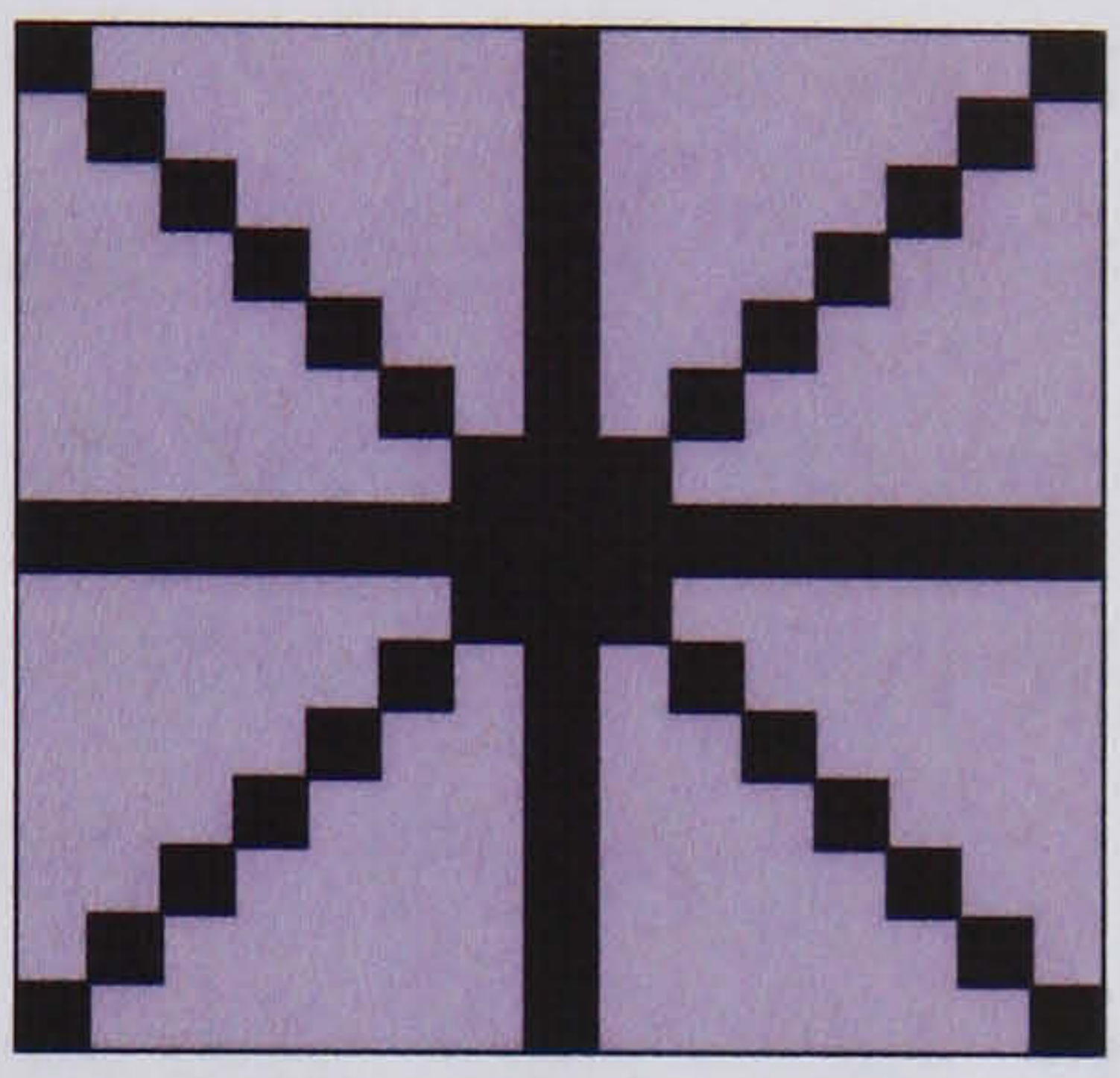


Figure 5.20: The masking stimulus in the axis of reflection experiment

5.5.4 Procedure

The procedure was the same as in the first experiment except the participants had only one compulsory break in order to reduce the overall experiment time. The range of ISIs was altered to 0, 14, 28, 56 and 154 milliseconds. This was to try to maintain a focus on early visual processes.

As in the previous experiments participants were presented with a target stimulus followed by the masking stimulus after a variable ISI and then a final stimulus that either was the same as the target or had the dots at a different distance. The participants were offered a forced choice and asked to identify if two dots in the final stimulus were the same distance apart as the dots in the target stimulus. Each choice image shared the same line of reflection as the target stimulus and only distance was varied. Prior to starting the main trials participants had to get over 80% correct on a series of practice trials, the practise trials were the same as the main trials except the ISI was 500 msec so that the participant could get used to making the distance judgements. The stimuli were presented in a random order throughout the experiment, in both the practise and main trials, in order to remove any cueing effects. The experiment took approximately 15minutes to complete.

5.5.5 Results

One factor that may have affected the saliency of the checkerboard patterns in the main masking experiment was that of trying to accommodate the entire image within the participant's window of attention. Therefore in this experiment the distance between the reflected dots was varied to test for any differences across the target stimulus area. The results show that dots presented closer to the line of symmetry, i.e. the near condition, were correctly identified more frequently than those presented towards the edge of the image, i.e. the far condition (Figure 5.21). Non-parametric tests were used as the data are not normally distributed. There was a highly significant difference between the dots presented in the near condition, mid conditions and those presented in the far conditions (Kruskal-Wallace test: $\chi^2 = 84.410$, df = 2, p <0.001). Therefore dots presented closer to the axis of reflection were more readily identified.

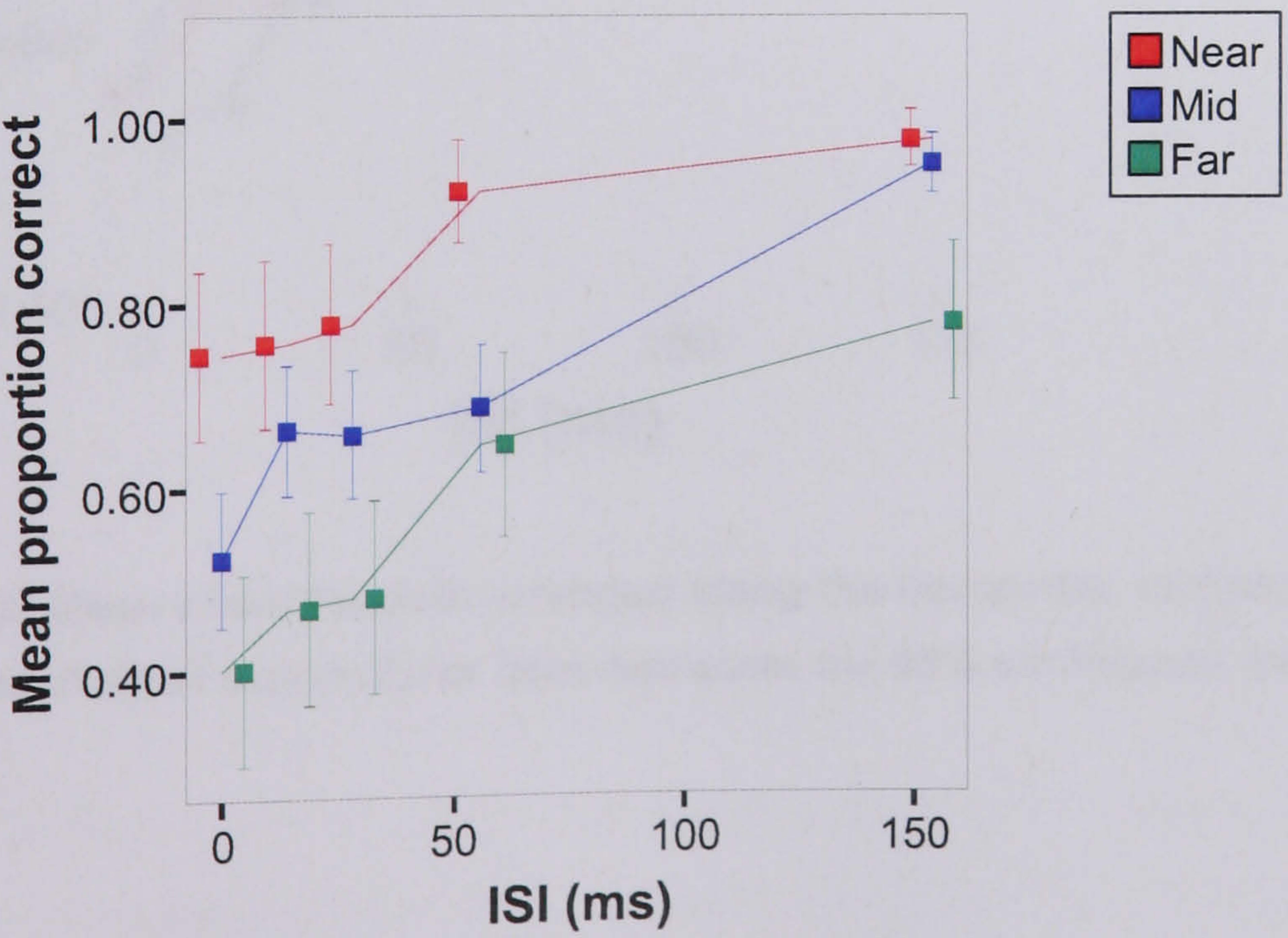


Figure 5.21: Mean score for dots spaced at different distances from the central fixation point. Error bars represent the 95% confidence intervals.

Moreover, those dots that were reflected across the vertical axis were correctly identified more frequently that those that were reflected across the diagonal or horizontal, see Figure 5.22. As the results do not show any homogeneity of variance (Levene = 33.650; df = 2, 1797; p <0.001) and are not normally distributed a Kruskal-Wallis test was used to examine the differences between the median values of the different conditions (n = 15, χ^2 = 17.19, df 2, p <0.001). The bias towards accurate matching of distance across the vertical axis is in accord with previous studies that state a general perceptual advantage for reflection across the vertical axis compared to the diagonal and horizontal (Dakin & Herbert, 1998; Dakin & Hess, 1997; Gurnsey, Herbert & Kenemy, 1998).

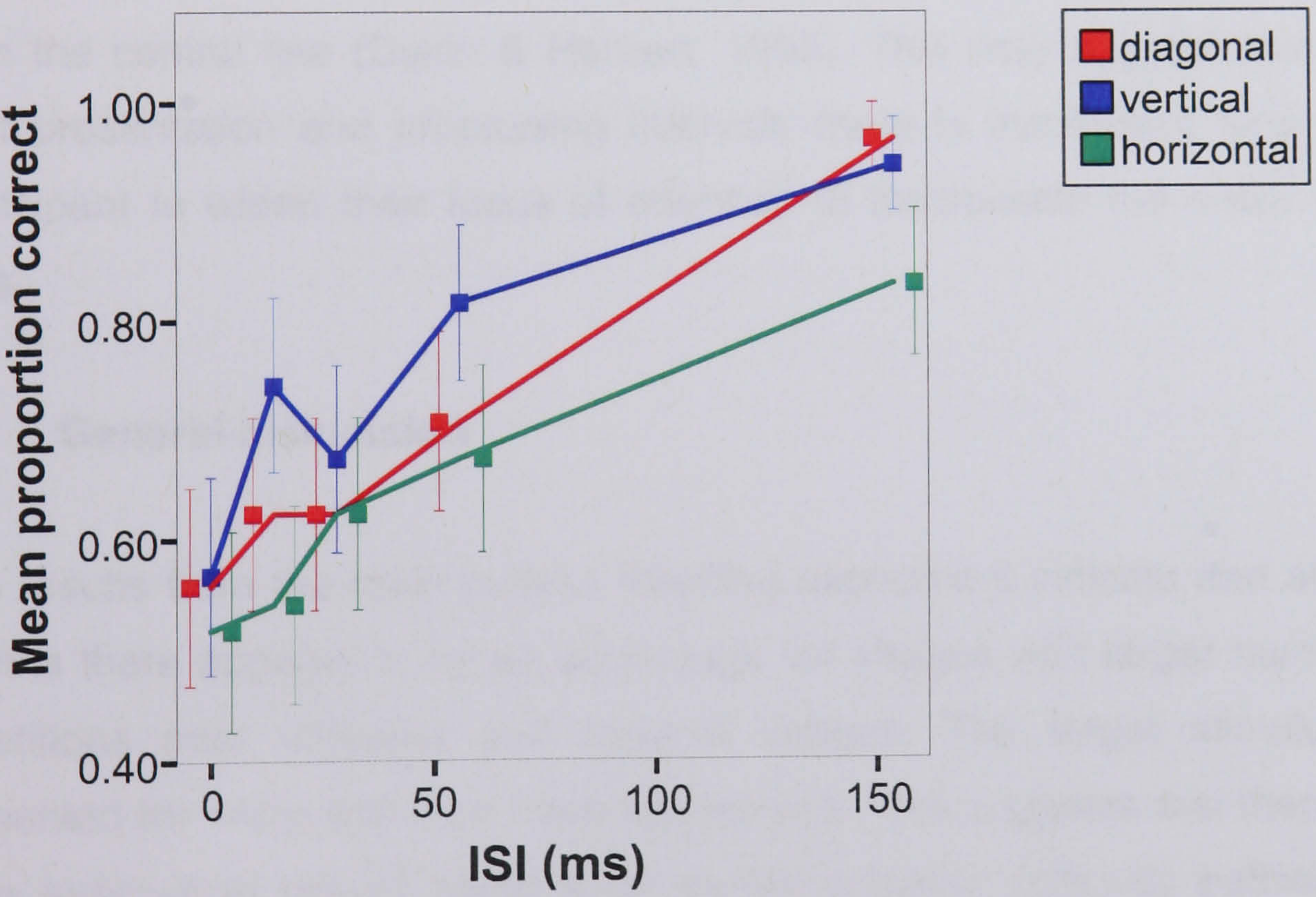


Figure 5.22: Mean score for dots arranged along the horizontal, vertical and diagonal of the field of vision. Error bars represent the 95% confidence intervals.

5.5.6 Discussion of axis of reflection experiment

The results of the axis of reflection experiment support the findings of earlier studies in that reflection across the vertical axis appears to be more salient than that across the horizontal (Dakin & Hess, 1997; Gurnsey, Herbert & Kenemy, 1998). This would suggest that in the checkerboard masking experiments different factors were operating that resulted in a contrary bias towards reflection across the horizontal axis.

The distance effect in this experiment could imply a restriction in the focus of attention within the masking experiments as only the distances closest to the line of reflection, i.e. the near condition, were readily identified. Those dots presented closer to the central line of reflection will lie more comfortably within the field of binocular vision than those that are presented at greater distances from the central line (Dakin & Herbert, 1998). This may suggest that during brief presentation and processing intervals there is insufficient time for the participant to widen their focus of attention to incorporate the entire display area.

5.6 General discussion

The results from the main pattern masking experiment indicate that at an ISI of 0ms there appears to be an advantage for images with larger numbers of repetitions over reflected and random images. The target stimulus was presented for 14ms and then instantly masked. This suggests that there could be a subcortical pre-V1 route such as the superior collicular pathway that allow for sufficient information regarding the spatial properties of the image to be processed and accurate judgements to be made. However, the poor accuracy for reflected stimuli at the lower ISIs (<14ms) suggests that in identifying these types of patterns there may be a requirement for top down processes involved with object recognition. This can be argued as at the higher ISIs, >96ms, there is a greater accuracy for reflected images when compared with repeated and random images. This greater accuracy could be the result of object recognition and template matching. For the repeated patterns there appears to be less accuracy at these higher ISIs compared to reflection and this could be due to a change of processing strategy at around 50ms, i.e. ISIs of approx 42ms, when there is a switch from global processing of the spatial properties to a point-by-point analysis of the stimuli.

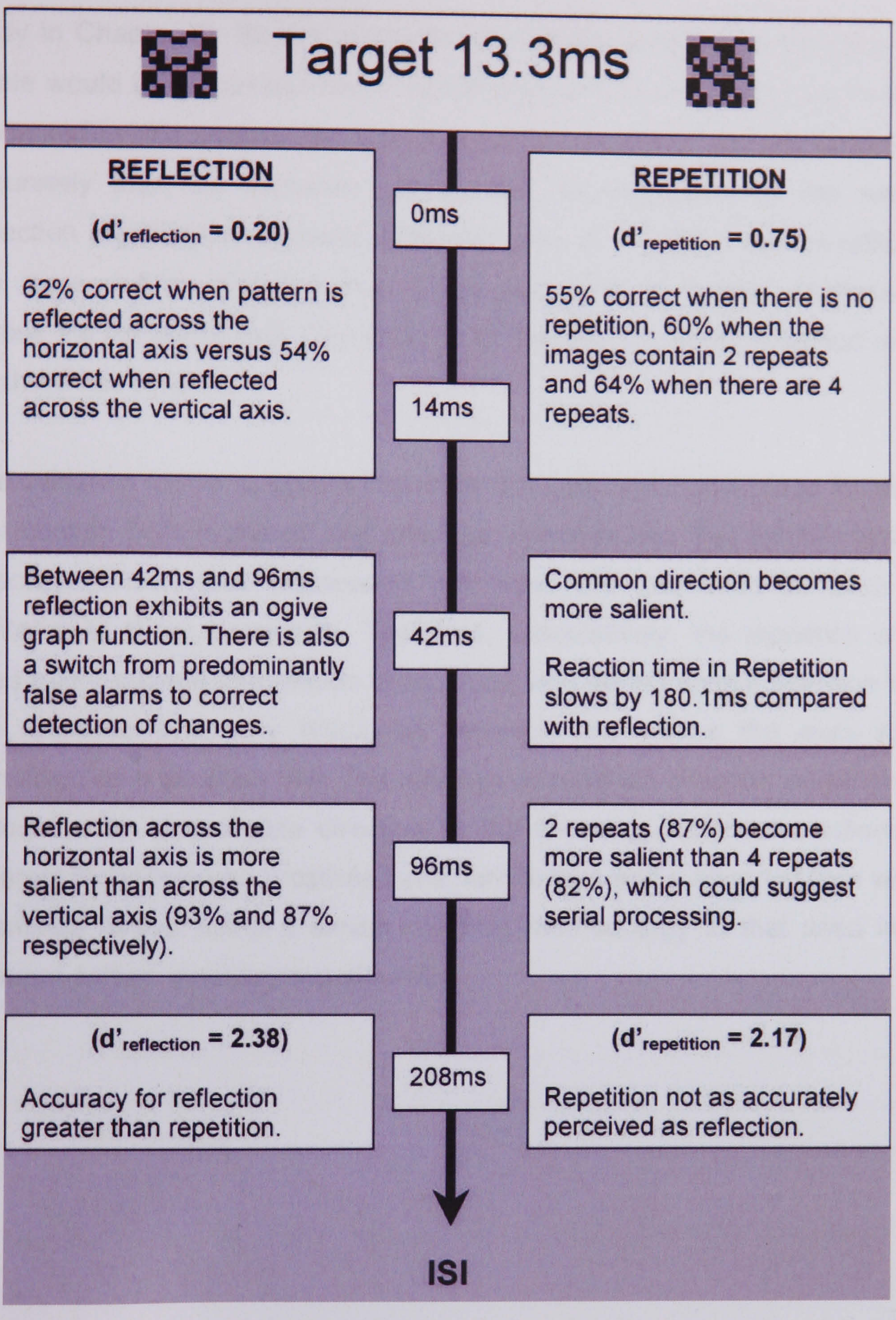
The bias in accuracy towards reflection at the higher ISIs is in accord with the representational theories of symmetry perception (van der Helm & Leeuwenberg, 1996; Baylis & Driver, 1995; 1993) that suggest a serial processing strategy for repeated stimuli and a rapid global processing strategy for the reflected stimuli. However, the bias towards repetition at the lower ISIs would suggest a simplicity theory (Chater, 1996) whereby the minimal information required is utilised and extrapolated across the spatial area.

Between ISIs 42ms and 96ms there was a rapid increase in accuracy for all of the pattern conditions. This appears to be a threshold point where sufficient processing has occurred for accurate identification of the target patterns, i.e. the target stimulus signal is being detected above the background noise of the masking stimulus. This could suggest that around this time significant re-entrant processing of the images is occurring. This trend is common for all of the stimulus types and therefore suggests that this is a point during visual processing when all stimuli are being processed in a similar fashion. This could reflect significant processing in area V1, 40ms to 60ms post stimulus presentation (Bullier, 2001).

The axis of reflection appears to have a significant impact on the processing of the checkerboard stimuli with patterns reflected across the horizontal axis being perceived more accurately than those reflected across the vertical axis (section 5.3). The subsequent axis of reflection experiment (section 5.5) shows that even at these low ISIs the vertical axis can still have a perceptual advantage. This provides two conflicting views on the importance of the axis of orientation in the perception of visual stimuli. One possible explanation for this dichotomy could be that in the checkerboard scenario the information content is greater than in the dot experiment scenario. The checkerboard scenario would therefore require increased attention to assimilate all the information provided. However, in the dot experiment the information is minimal and attention is consistently focused at the centre of the target images resulting in the increased accuracy for perceiving dots proximate to the vertical axis of reflection. In the checkerboard stimuli there was a tendency for participants to report that they had a bias towards looking at one particular hemifield of the image (see Appendix E for summary of participant comments). If there was a perceptual bias towards the left hand side of an image, then reflection across the horizontal axis would be more salient than across the vertical as the participant does not fully attend to the right half of the image. Therefore the half of the image reflected across the vertical axis is not being fully attended. This might also benefit repetition in that again there is no requirement for the transformation of the perceived area and the known elements can simply extrapolated across the checkerboard. This would reflect the idea that participants are extrapolating the image using the simplest strategy (Sharroo & Leeuwenberg, 2000). This also would support the least variant bias suggested by Attneave, (1954) and Handel & Garner (1965), in that there is no attempt on the participant's part to imagine a further variant as the result of reflection or rotation of the image they have perceived.

The role of the number of variants that an image can possess as the result of reflection and rotation did not have a conclusive effect on the accuracy results of the participants. The results appeared to reflect the random vs. reflection graphs from which the data were derived (see Figure 5.12). As the stimuli were randomly generated to avoid aesthetic bias on the part of the experimenter, there was no guarantee of obtaining a pattern that contained only 1 variant. However from the results obtained it could be inferred that a reduction in the number of variants is one of the properties that may contribute to the saliency and definition of reflective patterns. The results of the pilot study (Chapter 3) showed that there was a greater preference for patterns that possessed fewer variants and this could suggest that a reduction in the number of variants might reflect a stronger aesthetic quality rather than an information processing advantage. However, this aesthetic bias itself could be the result of a preference for visual stimuli that contain redundant information and are easier to process.

In conclusion the results show the early advantage for repetition in visual processing and a later advantage for reflection. The results also suggest that during early visual processing a variety of strategies could be adopted, including the use of spatial information at early ISIs and top-down processes at higher ISIs, with each giving a perceptual advantage to a particular symmetry type, namely repetition and reflection respectively. The experiments also highlight the need to investigate hemispheric biases in the perception of briefly presented visual stimuli. This issue is investigated further in Chapter 8. A summary of the main outcomes for the experiments in this chapter is presented in Figure 5.23.



($d'_{reflection} = 0.20$)

62% correct when pattern is reflected across the horizontal axis versus 54% correct when reflected across the vertical axis.

($d'_{repetition} = 0.75$)

55% correct when there is no repetition, 60% when the images contain 2 repeats and 64% when there are 4 repeats.

Between 42ms and 96ms reflection exhibits an ogive graph function. There is also a switch from predominantly false alarms to correct detection of changes.

Common direction becomes more salient.

Reaction time in Repetition slows by 180.1ms compared with reflection.

Reflection across the horizontal axis is more salient than across the vertical axis (93% and 87% respectively).

2 repeats (87%) become more salient than 4 repeats (82%), which could suggest serial processing.

($d'_{reflection} = 2.38$)

Accuracy for reflection greater than repetition.

($d'_{repetition} = 2.17$)

Repetition not as accurately perceived as reflection.

Figure 5.23: Summary of findings from the masking experiments (sections 5.3, 5.4 & 5.5)

5.7 Application to the study of natural patterns

The configuration and arrangement of features in the human face are an important determinant in what people classify as being face-like (see pilot study in Chapter 3). So the predominantly reflective nature of the face as a whole would be advantageous in recognition, as in the masking experiments presented in this chapter the reflected stimuli in general are identified more accurately than the repeated stimuli. And as suggested by the axis of reflection experiment, elements reflected close to a vertical axis of reflection are more readily identified than those presented at greater distances or across the horizontal axis. The features of the face, i.e. eyes, nose and mouth all share this property.

The evidence further suggests that there is a perceptual advantage for stimuli that contain both repeated and reflected elements and that exhibit common direction. Within face processing, the eyes are one such stimulus that contains all these properties. Therefore, speculatively, the repetition of the eyes might provide information redundancy and attract spatial attention while the reflective symmetry holds the attention and allows the eyes to be perceived as a grouped unit. The salience of common direction would aid the determination of eye gaze direction. In the following chapter the saliency of different facial features presented in a normal face and a distorted face will be examined further using a similar masking methodology to that used in the abstract pattern masking experiments.

Chapter 6: Investigation into the early visual processing of face patterns

6.1 Introduction

The factors that contribute to making a face look face-like comprise of more than just the features that the face contains but also the spatial arrangements of those features (See Chapter 3: section 3.4). In a pilot study, 93 participants generally rated a face that contained no features but possessed 3 dots arranged in an inverted triangle within an oval as being more face-like than one based on realistic facial features presented out of their usual spatial context but within a normal face outline (see Figure 3.10, Chapter 3). This suggests that the patterning within the face is probably a very important factor when attributing characteristics and face-like properties to an image.

The evidence from the pilot study and from previous studies on grouping within pattern perception (Kurylo, 1997) would suggest that the recognition of faces would occur between 80 and 120ms post image presentation, as this is the point where detection of the grouping of stimulus elements occurs. However, this is assuming that when a face is encountered it is processed entirely in a feed forward/ bottom-up process and that identification only occurs after extensive re-entrant processing between primary visual areas and the areas of the brain within the temporal and frontal cortices associated with face perception. If there are top-down processes occurring, whereby faces are anticipated within the visual system, then this timescale of recognition can be shortened considerably.

Several different time courses for the detection of faces within the visual system have been put forward based upon event related potentials (ERPs) and brain imaging techniques. These include the recognition of a previously seen face at approximately 50ms post stimulus presentation (Seeck et al., 1997) and activation of face receptive areas within the temporal lobe at approximately 80ms (Oram & Perrett, 1992). This evidence would suggest that there is an early top-down influence on face perception. Therefore once a face is recognised minimal processing is required to identify the individual. It is suggested that this recognition occurs before the grouping of patterns via proximity at approximately 87 ms and by alignment at 118.8 ms (Kurylo, 1997). This would suggest that unlike novel patterns, faces are not processed in terms of the individual features but perhaps holistically against a configural template. This configural template may be based upon the imposition of a simple pattern template. This pattern template, in conjunction with the properties of individual features, could provide the basis for the basic face recognition units as suggested by Bruce and Young (1986).

In this section it is the investigation of these possible face recognition units that is of interest. The face recognition units could impose a top-down effect on face perception that is occurring at early stages of vision approximately 50ms after the face has been seen (Seeck et al., 1997). At this early stage of vision only basic properties of the stimulus are identified via bottom-up processes. These include the orientation, contrast and spatial qualities of the stimulus (DeValois & DeValois, 1988; Hubel & Wiesel, 1968, 1977). As illustrated in Figure 5, section 2.4, the process of pattern identification involves "pattern recognition units" post detection of the contrast, colour, edges and spatial properties of the image. For faces the detection of contrast, boundary and spatial properties would prove vital in picking up the arrangement of the features. Features that are high contrast and repetitive will be particularly useful in rapid matching of recognition units with information contained within the feed forward processes of the early visual system. The eyes for example are a particularly salient high contrast feature that is not only reflected across the vertical axis but also contains repeated elements. Therefore pattern recognition units sensitive to this information will create redundancy within the information processing system and allow for rapid activation of areas of the cortex associated with face recognition. Specific pattern types, such as a face, may contain patterned properties that are detectable at early stages of visual processing and would therefore be advantageous in the application of a top-down face recognition template.

Numerous patterns are present within the face both at the featural and at the global level. However, the features themselves can be seen as the corners of a pattern, i.e. a polyhedron or triangle that maps the spatial properties of the features (Barton et al., 2001). If the eyes and the mouth are considered as being the corners of a triangle and the nose the line of reflective symmetry, then any distortions to the angle of the nose and the line of symmetry could have a detrimental effect on face identification. The eyes have a particularly important role in defining the configural properties of the face as the repeated nature of the eyes will mean that they account for a greater proportion of the spatial information than other features. For example if the distribution of the features are considered as points on a triangle (See Figure 6.1) then the eyes will account for two of the corners and an entire edge, this could mean that in detecting the bilateral symmetry of the face the eyes will be the primary feature detected. However, if the face is distorted so that the line of reflective symmetry suggested by the nose does not match the triangular arrangement of the eyes and mouth, then the saliency of the features might be reduced (Figure 6.1). In such a condition, as illustrated in Figure 6.1, there is a spatial mismatch between the repetition of the eyes and the suggested line of reflection inferred by the nose thus the sense of a facial “pattern” is lost.

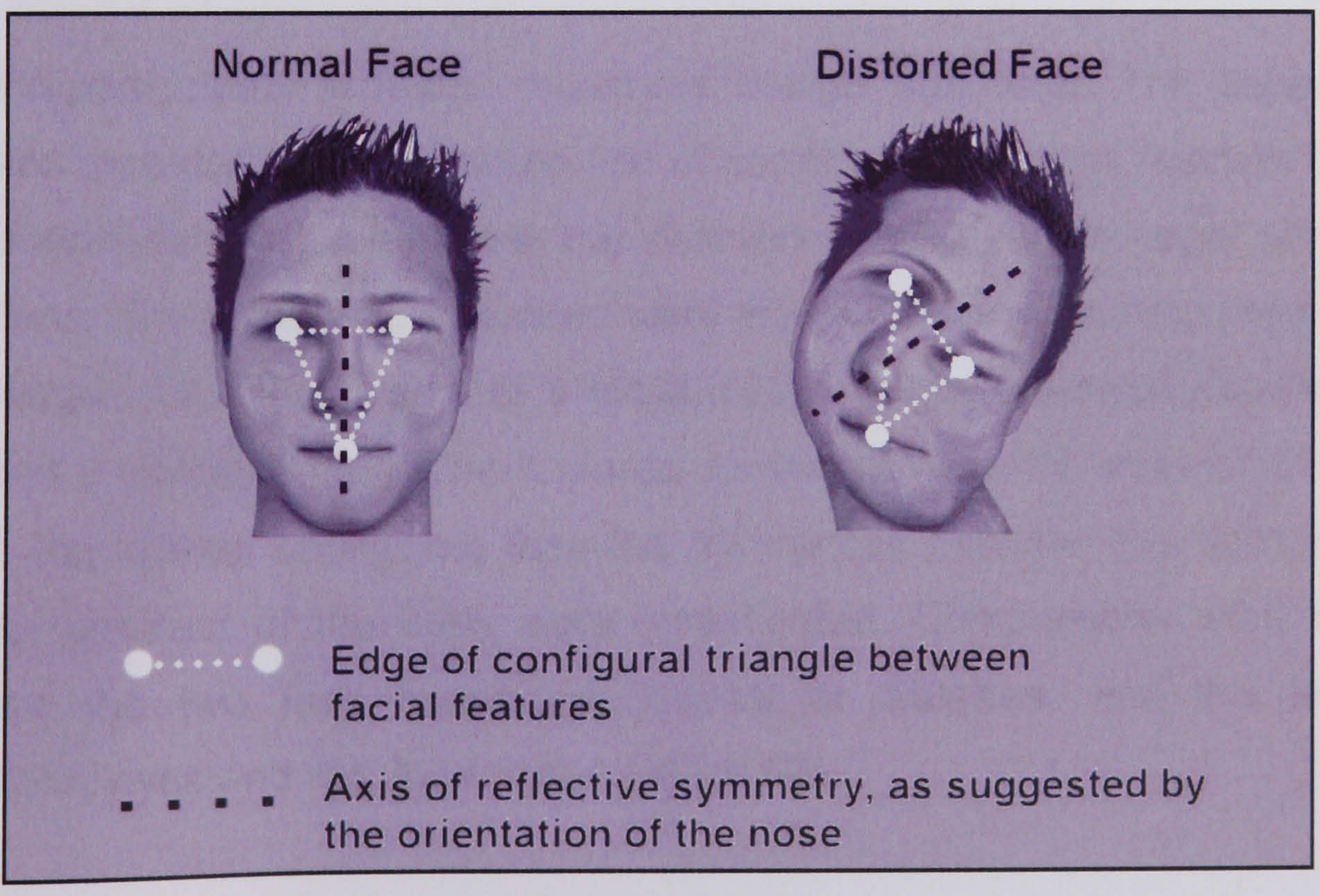


Figure 6.1: The features of the face represented as points and lines of reflective symmetry of a configural triangle.

Various patterned properties of the face, including the global reflective symmetry and local repeated features, provide redundant information that can allow for rapid identification and aid top-down processing. As a regularly experienced social pattern it would be advantageous for faces to be processed as rapidly as possible from only a brief glance. Therefore it would be expected that faces are a special case in pattern processing that do not require serial or predominantly feed forward processing, as observed in the non-ecological checkerboard patterns used in Chapter 5.

The aim of the following experiment is to investigate the time course of perception for different featural elements and configural face types within early visual perception. A masking methodology was used to see how much facial information could be encoded by early visual processes in a short time frame.

6.2 Methods

6.2.1 Design

A within-participants repeated measures design was used. The dependent variables recorded were the proportion of correct answers and reaction times. The independent variables were the changes in ISI and the target stimulus conditions. The conditions examined were the proportion of correct responses for changes, i.e. loss or gain of a facial feature within a normally configured face and a distorted face. The features compared were the eyes and mouth and in the normal configured face the differences between the normal and reduced contrast of the eyes were investigated. Comparisons were made between the two face conditions, normal or distorted, and the feature conditions, eyes and mouth, across several ISIs.

6.2.2 Participants

Twenty-one participants, 13 female and 8 male were obtained from an opportunistic sample at the University of Gloucestershire. All participants were offered £5 compensation for their time regardless of the number of trials they completed. All participants were aged between 19 and 40 years old all and had normal or corrected-to-normal vision. All participants provided their written informed consent prior to taking part in the experiment.

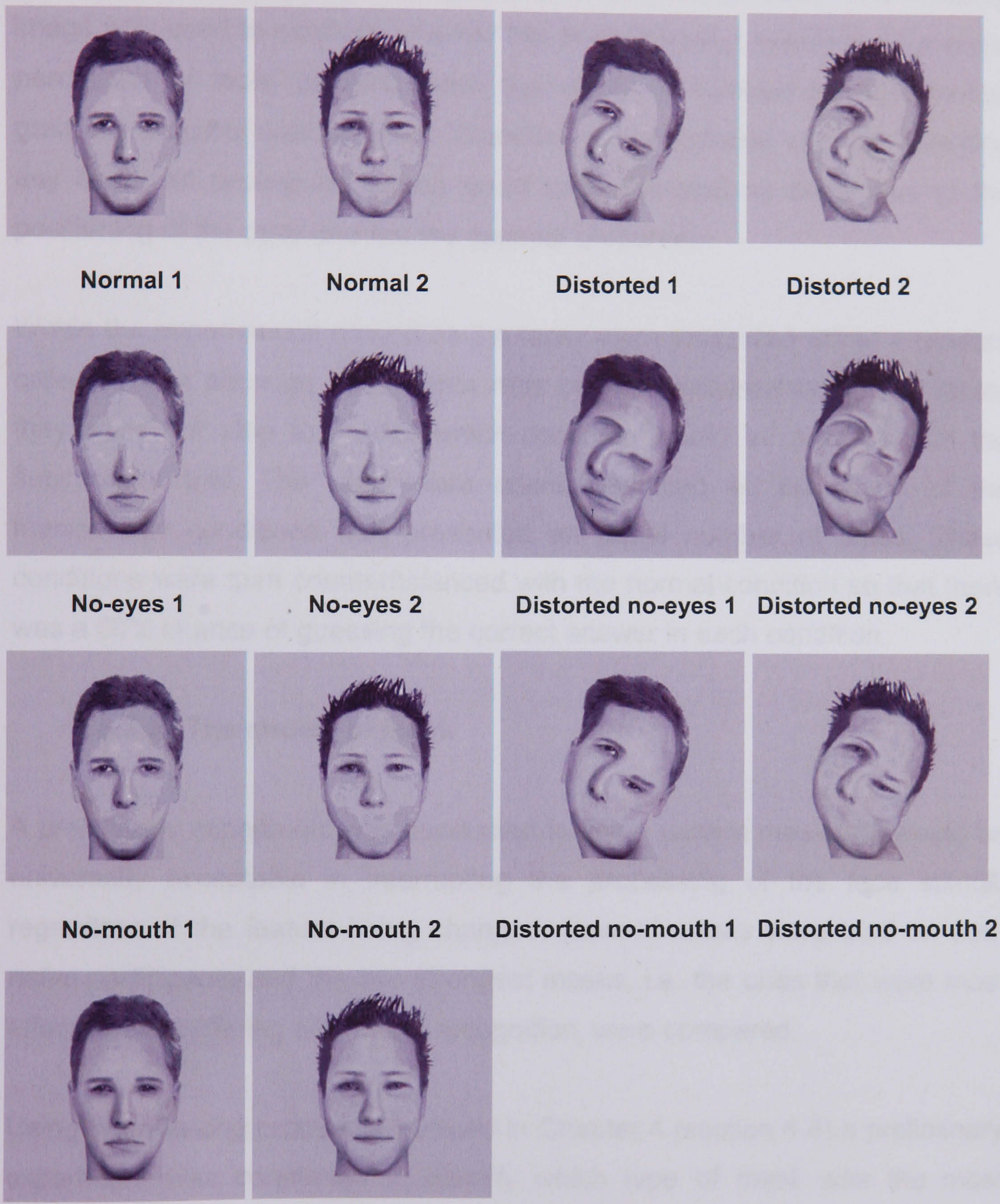
6.2.3 Apparatus

The experimental apparatus was the same as described in Chapter 4, section 4.8.

6.2.4 Stimuli

The stimuli comprised of photo fit images created using FACES software (InterQuest Inc., 1998). The face images were manipulated using PaintShop Pro 8. The changes to the stimuli involved the removal of the eyes, mouth and changes to the eye contrast (See Figure 6.2). There were 14 different face types. The stimuli were presented at a size of 21cm x 21cm, and presented in the centre of the display at an approximate visual angle of 18°. All stimuli were presented in greyscale. Two basic faces were created and were then manipulated to create all the conditions. The amount of hair in each stimulus was kept to a minimum so that focus would be maintained on the face and what constitutes a face. Masculine faces were used, as culturally male faces with short hair are more commonly encountered than feminine faces with short hair. Other features that define masculine faces such as facial hair were not included. As an ecologically valid visual stimulus, the faces were designed to be as natural looking as possible and with features configured in accord with the triangular arrangement illustrated in Figure 6.1.

The faces were also altered to examine the effect of removing the inferred line of symmetry implied by the nose as a visual cue in the perception of the featural configuration (see Figure 6.1). The faces were distorted using the "Twirl" function in PaintShop Pro 8. The faces were twirled by 90° around a central point between the two eyes at the top of the nose. This resulted in a misalignment between the central axis of reflection suggested by the nasal ridge and the configural triangle implied by the eyes and the mouth (see distorted images in Figure 6.2).



Normal 1 Normal 2 Distorted 1 Distorted 2

No-eyes 1 No-eyes 2 Distorted no-eyes 1 Distorted no-eyes 2

No-mouth 1 No-mouth 2 Distorted no-mouth 1 Distorted no-mouth 2

Low eye contrast 1 Low eye contrast 2

Figure 6.2: The basic stimuli used in the facial masking experiment. In the low contrast condition the contrast between the sclera and the iris was reduced by 70%.

As contrast has been suggested as a particularly salient property in feature detection (Franconeri, Hollingworth & Simons, 2005; Posner, 1980) another condition was introduced where the contrast of the eyes was significantly reduced. The contrast between the sclera and the iris of the normal face condition was reduced by 70% (see Figure 6.2, bottom row). The resulting image was used to examine whether the eyes remain a salient feature in the perception of facial patterns when the effect of contrast as an attention grabbing property was reduced. Therefore in the reduced contrast condition any observed perceptual biases could be considered as being due to the positioning of the eyes and not the contrast properties.

Within the experimental procedure the faces were presented within a random order so that although participants may become accustomed to the faces, they were not able to predict which condition would be presented in the subsequent trial. The trials were counterbalanced so that each of the manipulated conditions was presented an equal number of times. These conditions were then counterbalanced with the normal condition so that there was a 50% chance of guessing the correct answer in each condition.

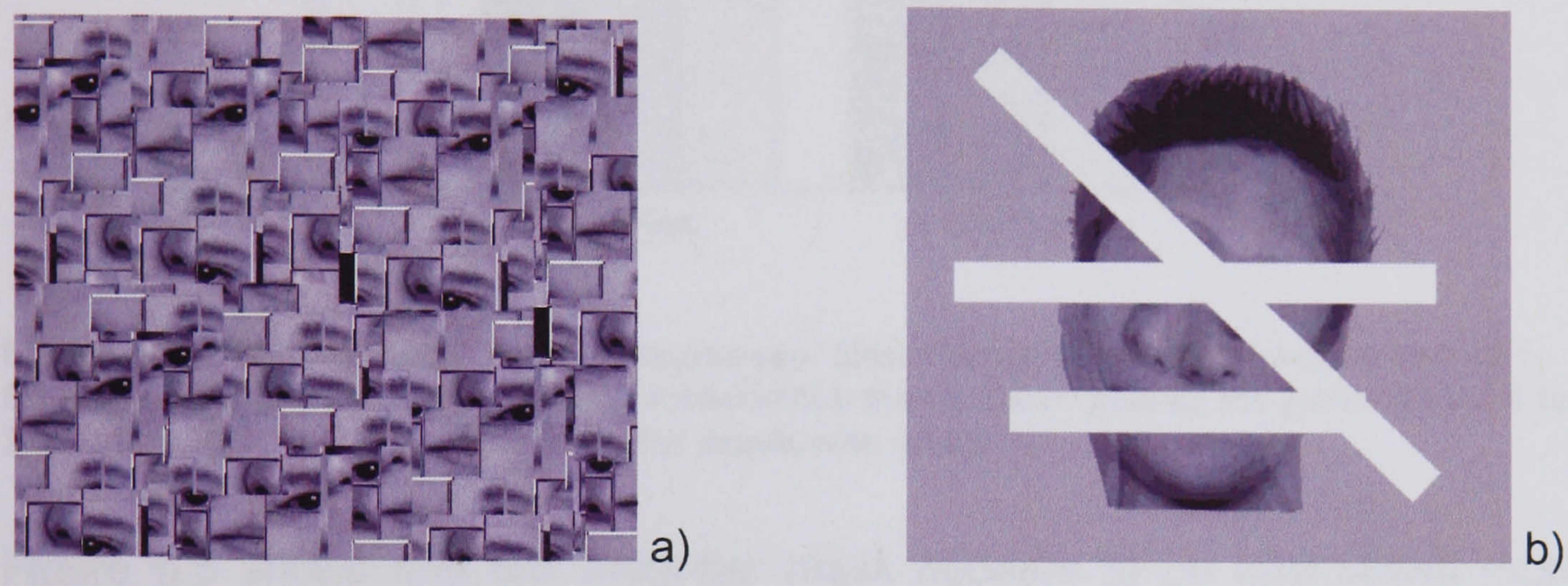
6.2.5 The choice of mask

A preliminary experiment was conducted to find a pattern mask that would be universally acceptable in interrupting the processing of the face stimuli, regardless of the feature being changed. Several masks were tried on non-naïve participants and the two strongest masks, i.e. the ones that were most effective at interfering with target recognition, were compared.

Using the masking procedure outlined in Chapter 4 (section 4.8) a preliminary experiment was conducted to identify which type of mask was the most effective at interrupting early visual processing. Three participants, all of who were familiar with backward masking experiments, took part in this preliminary experiment. The participants had to detect whether or not a second image presented post-masking was the same as the target face image.

In previous face perception experiments the masks either comprise of a jumbled image made up of elements of the target picture (Moscovitch &

Radzins, 1987) or a high contrast mask that blocks out only those areas where changes might be occurring (Rolls & Tovee, 1994). In choosing an appropriate mask both types were investigated in a preliminary test using a backward masking procedure similar to that for the main experiment. The two mask types are illustrated below (Figure 6.3). The target stimuli used in this preliminary experiment were selected randomly from the main experiment and the same stimuli were used for both types of mask (see Figure 6.3).


a)

b)

Figure 6.3: The 2 masks a) jumbled face mask and b) the white bar mask

The most effective mask was judged to be the one that inhibits processing of the target to a greater extent, resulting in a lower or reduced number of correct responses. Figure 6.4 shows the overall proportion of correct responses for each participant for each masking condition. The overall scores for each participant suggest that the mask consisting of the merged target faces with white bars across the main features is the most effective. The mean scores for each mask were compared using a one-way repeated measures randomisation test to account for any autocorrelative effects as a result of the small sample size. It was shown that there was a significant difference in the distribution of scores ($p < 0.001$). The white-bar mask therefore appeared to be significantly more effective at blocking the target stimuli.

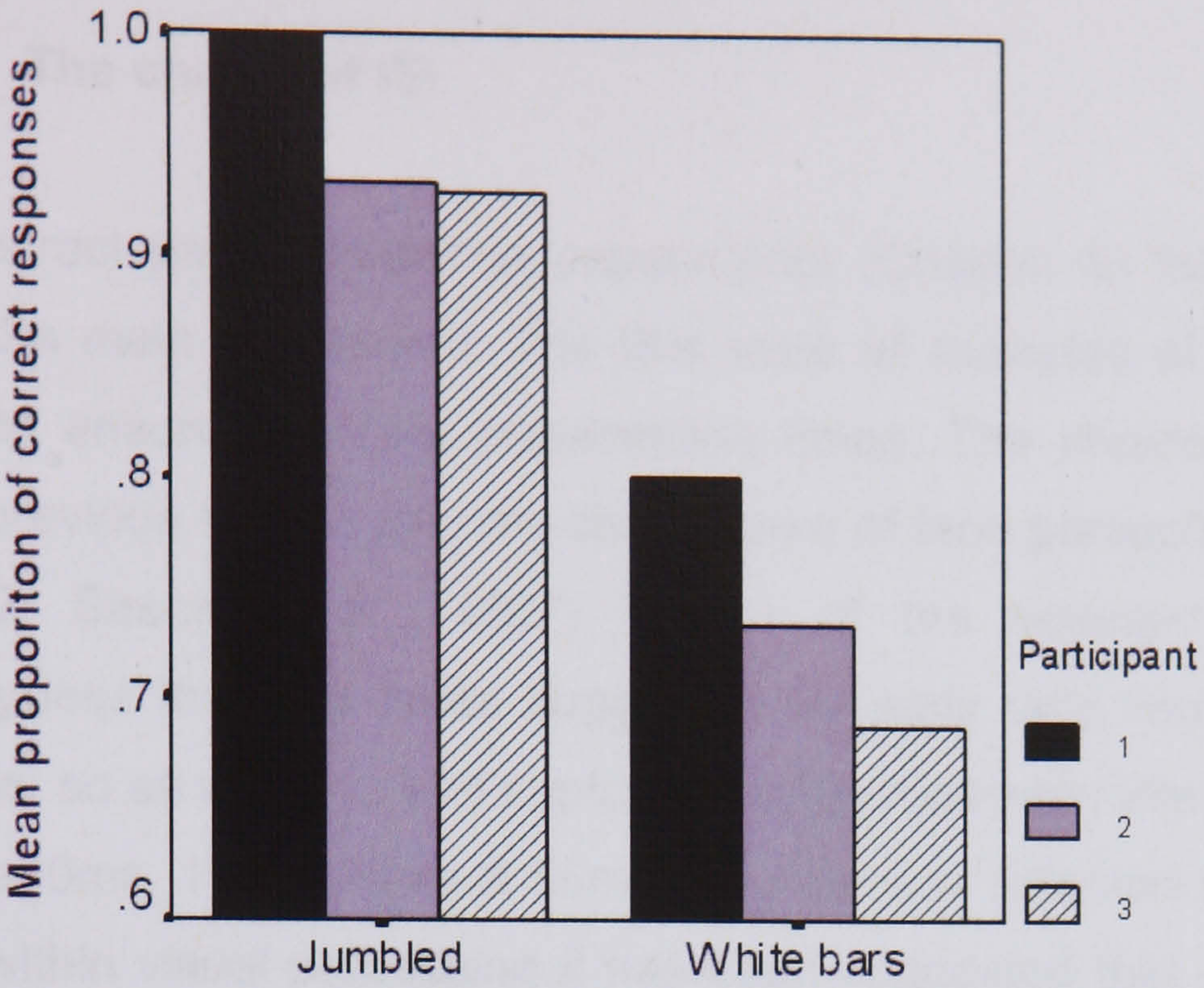


Figure 6.4: Distribution of correct responses. Mean scores for participants 1 to 3 of 1, 0.93 and 0.93 respectively for the jumbled-face mask. Mean scores for participants 1 to 3 of 0.8, 0.73 and 0.68 respectively for mask with white bars.

Figure 6.5 shows that the white-bar mask appears to be interrupting more visual processing at the lower ISIs. However, by 154 msec both masks appear to be working equally well suggesting that full pattern recognition is occurring at this stage.

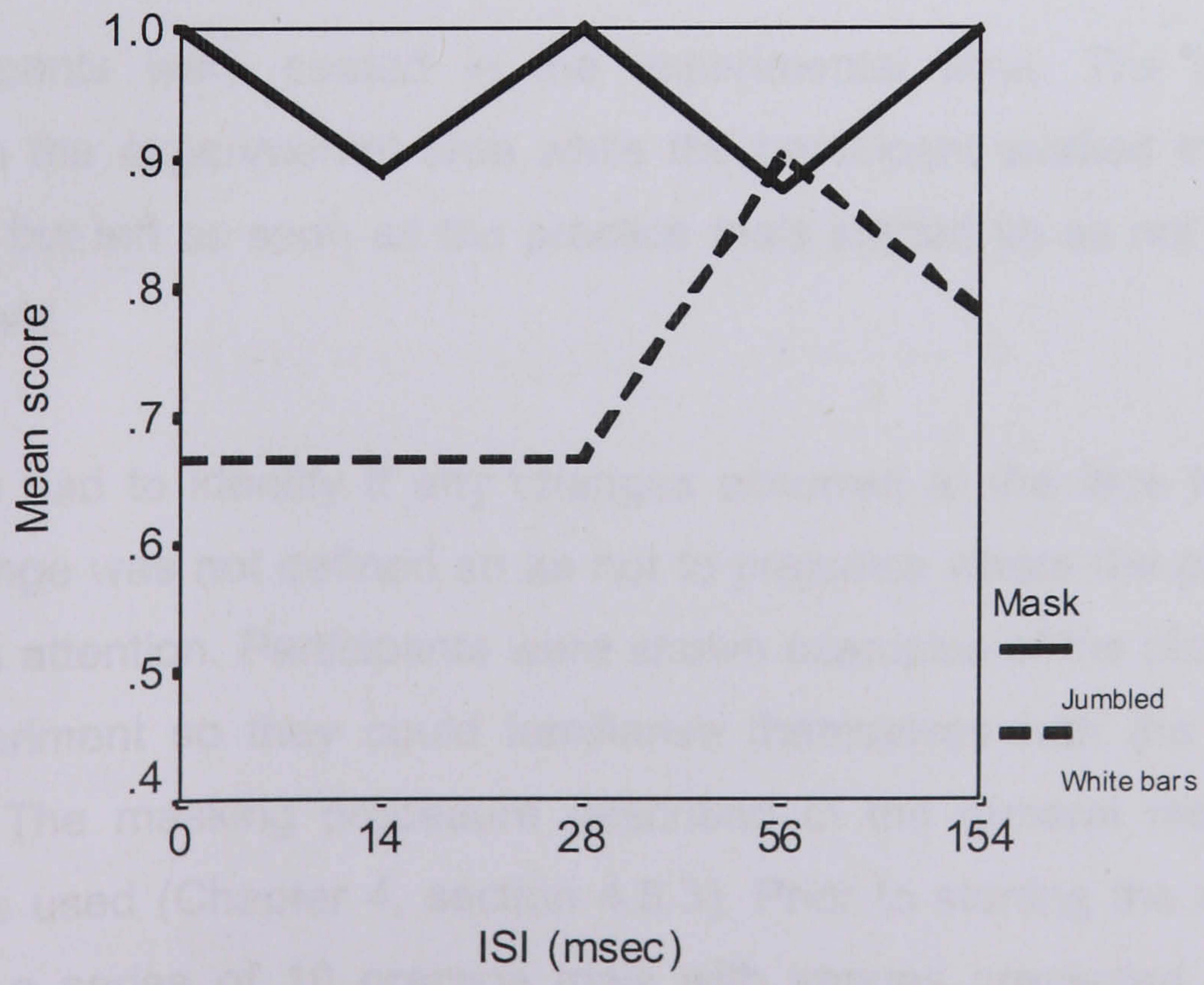


Figure 6.5: Distribution of correct scores across different ISIs for all participants.

6.2.6 The choice of ISI

As in the abstract pattern masking experiments (Chapter 5) five ISIs were selected for the main experiment. The ISIs were all multiples of the monitor refresh rate to ensure accurate presentation times. The choice of ISI was based upon previous studies into the time course of face perception (Oram & Perrett, 1992; Seeck et al., 1997). Four of the selected ISIs were predominantly less than the times suggested for early face recognition, i.e. 56ms and less, so as to be sure of capturing early processing intervals. These intervals were: 0ms, 14ms, 28ms & 56ms. One ISI was selected at 154ms as by this time within visual processing it has been suggested that areas of the brain associated with a conscious response to a stimulus are activated, i.e. motor areas (Van Rullen & Thorpe, 2001). Therefore, these times respectively represent points within visual processing prior to face recognition (<56ms) and post identification (154ms). These intervals were selected to allow for the identification of the facial properties that may be dominant in the construction of face selective pattern recognition units.

6.2.7 Procedure

The participants were seated in the experimental area. The researcher remained in the experimental area while the participant worked through the instructions but left as soon as the practice trials started so as not to distract the participant.

Participants had to identify if any changes occurred to the face image, the type of change was not defined so as not to prejudice where the participants would focus attention. Participants were shown examples of the pictures prior to the experiment so they could familiarise themselves with the keys and conditions. The masking procedure described in the general methodology chapter was used (Chapter 4, section 4.8.3). Prior to starting the main trials there were a series of 10 practice trials with images presented at ISIs of 500ms so that no masking would occur. Once the participants had achieved over 80% correct on the trial session they were allowed to continue to the main trials. All participants passed the practise session after one block. As explained in 6.2.5, in the main trials the ISIs used were 0, 14, 28, 56, 154 ms. These ISIs were selected to reflect those used in previous research into the time course of face perception.

If the participant detected a change then they were asked to press the "1" key and if they thought that there was no change they were asked to press the "2" key. The experiment took approximately 20 to 25 minutes and consisted of 135 main trials. The order of presentation was randomised and balanced between conditions to minimise priming or cueing effects. The general testing procedure was the same as that described in Chapter 4, section 4.8.

6.3 Results

6.3.1 Eyes and mouth

A repeated-measures within-participants 5 x 2 (ISI x facial features) ANOVA was conducted on the correct scores to determine whether one feature was more salient than another, i.e. the eyes or the mouth. There was a significant main effect for ISI, $F_{4,164} = 4.783$, $p = 0.001$, $\eta = 0.104$, however the effect size is quite weak. This is reflected in the predominantly level graph after ISIs of 56ms (see Figure 6.6). There was also a significant main effect for the feature that was changed, $F_{1,41} = 48.820$, $p < 0.001$, $\eta = 0.544$. This suggests that to the eyes were more apparent throughout the experiment with a reduced masking effect compared to that of the changes to the mouth. However, as illustrated by the reduction in the proportion of correct scores at 14ms there does appear to be a masking effect for detection of changes to eyes, however this effect reflects either a weak mask for eye stimuli or that eyes are pre-attentively processed. There was no significant interaction between the features and the ISI factors, $F_{4,164} = 1.121$, $p = 0.349$, $\eta = 0.027$. The means and standard deviations for the proportion of correct answers at each ISI for each condition are listed in Table 6.2.

Changes occurring to the eyes appear to be less detectable at 14ms, however the high proportion of correct answers at ISIs of 0ms suggest that the eyes, like the repeated patterns in chapter 5 can be perceived at a preattentive level. This could be due to the high contrast nature of the eyes or due to the repeated nature of the eyes and sensitivity towards this spatial arrangement.

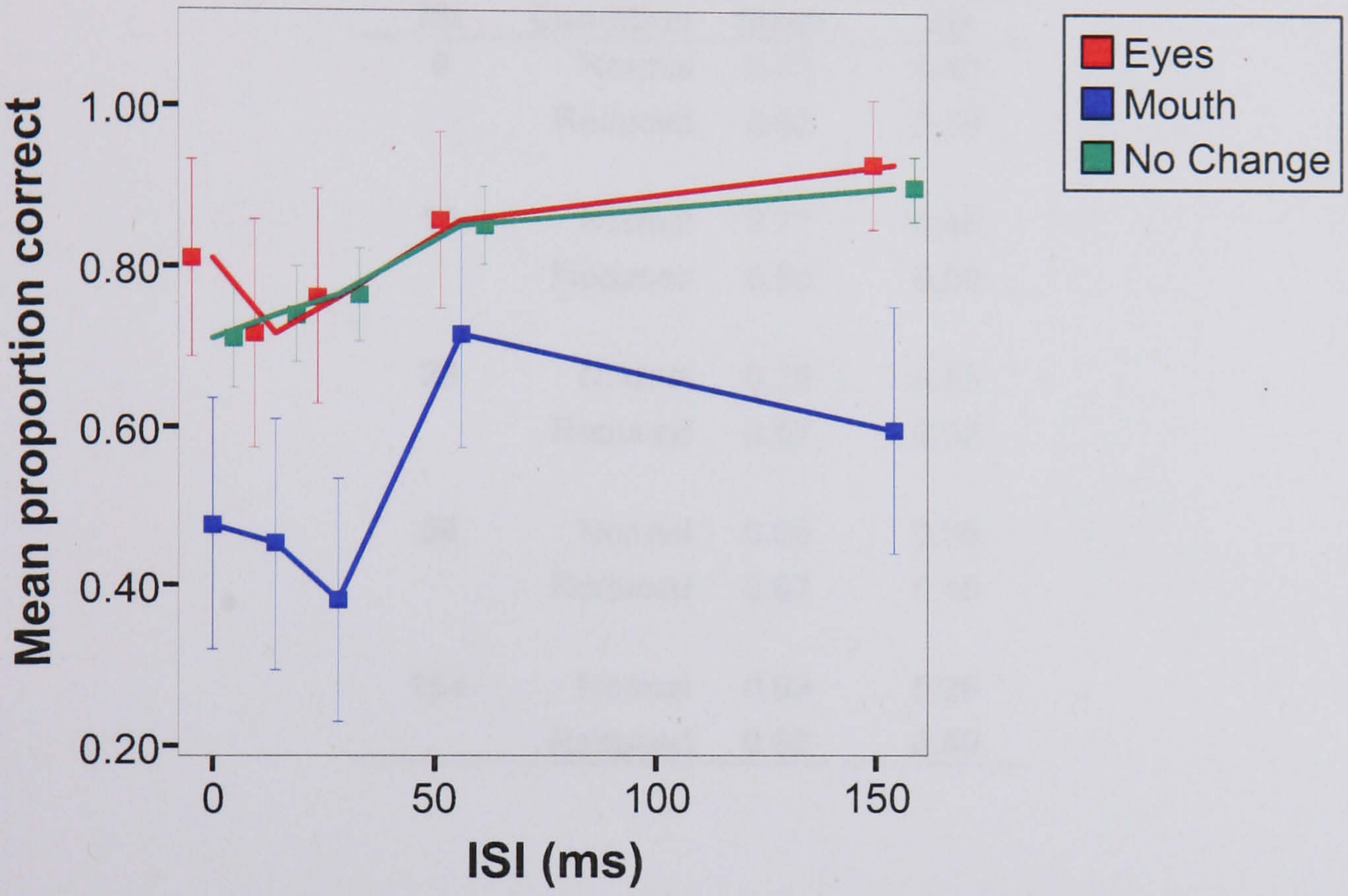


Figure 6.6: The mean proportion of correct answers for changes to the eyes and changes to the mouth. The errors bars represent the 95% confidence intervals.

6.3.2 Eyes and contrast

A repeated-measures within-participants 2 x 5 (Contrast x ISI) ANOVA was conducted on the proportion of correct responses. There was not a significant main effect of ISI, $F_{4,164} = 1.274$, $p = 0.282$, $\eta^2 = 0.03$. There was a main effect for the contrast of the eyes, $F_{1,41} = 17.220$, $p < 0.001$, $\eta^2 = 0.296$. There was not a significant interaction between the contrast of the eyes and the ISI: $F_{4,164} = 0.570$, $p = 0.684$, $\eta^2 = 0.014$. Changes occurring to eyes in the normal contrast condition are more readily detected than changes to the reduced contrast condition (see Figure 6.7). This suggests that the normal contrast eyes are capturing attention more readily than the reduced contrast eyes.

However, there was a slight masking effect for the normal contrast eyes at ISIs of 14ms. These results suggest that the high contrast nature of the eyes might play a significant role in the saliency of this feature.

Table 6.1: Means and standard deviations (SD) for the proportion of correct answers in the normal eye contrast and reduced eye contrast condition.

ISI	Condition	Mean	SD
0	Normal	0.81	0.40
	Reduced	0.62	0.49
14	Normal	0.71	0.46
	Reduced	0.60	0.50
28	Normal	0.76	0.43
	Reduced	0.57	0.50
56	Normal	0.86	0.35
	Reduced	0.67	0.48
154	Normal	0.93	0.26
	Reduced	0.62	0.49

Table 6.1 shows the means and standard deviations for the proportion of correct responses for the normal face condition and the reduced eye contrast condition. The mean proportion of correct answers is consistently greater in the normal face condition.

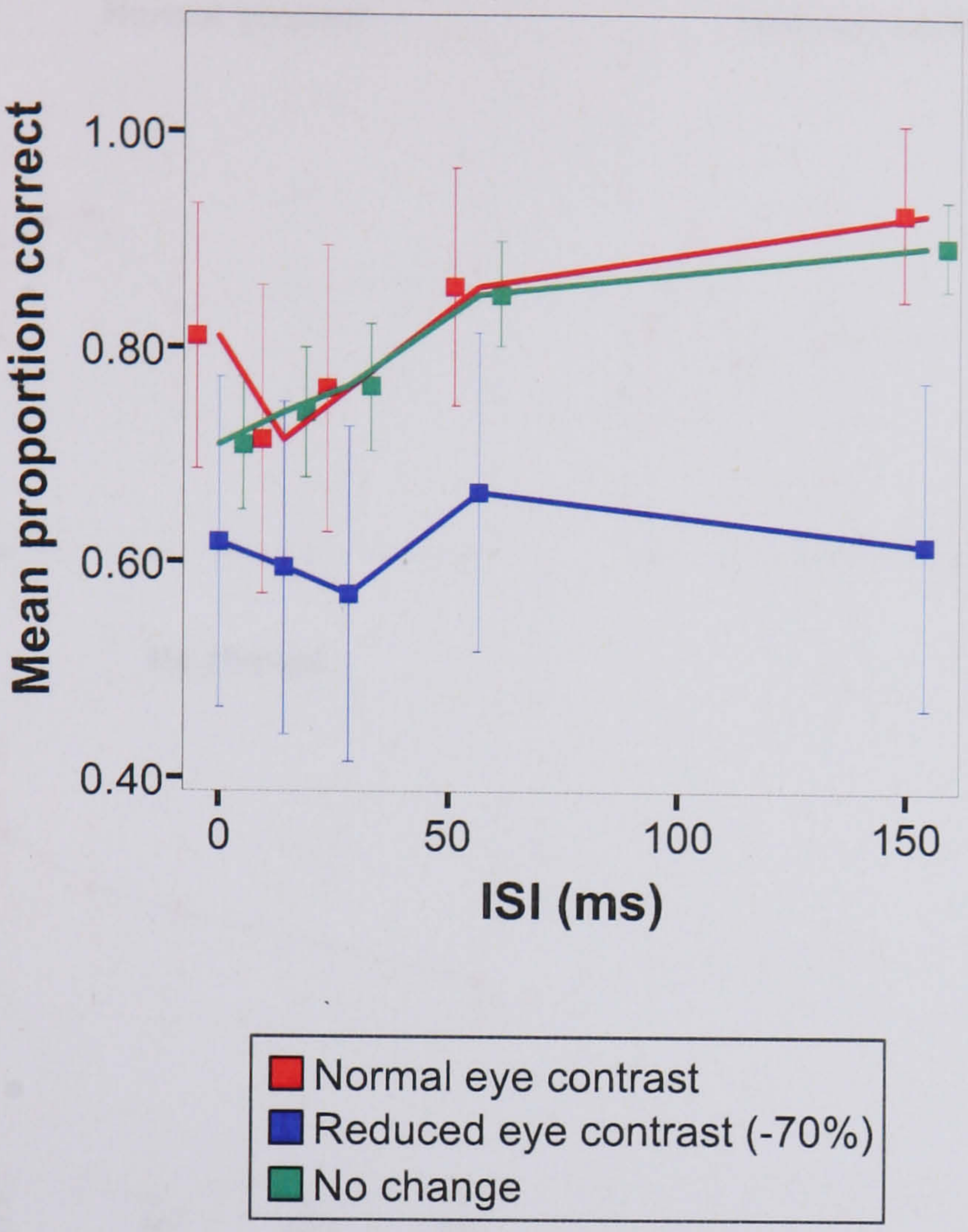


Figure 6.7: The mean proportion of correct answers changes to the eyes with normal contrast, eyes with a 70% reduction in eye contrast and for faces where no change occurs. The errors bars represent the 95% confidence intervals.

Figure 6.8 illustrates the mean reaction times for the normal eye contrast and reduced eye contrast condition. The graphs show a reduction in reaction time at approximately 56ms for the normal eye contrast condition and a reduction in reaction time at an ISI of approximately 28ms for the reduced contrast condition. In the ‘no change’ condition there is a continuous decline in reaction time with an increase in the ISI. This suggests that for the eye contrast conditions masking is occurring at the lower ISIs due to the slower reaction time. However after 28ms to 56ms there is greater certainty in participant responses, illustrated by the reduction in reaction time, suggesting that at longer processing intervals there is a reduced masking effect in the two contrast conditions.

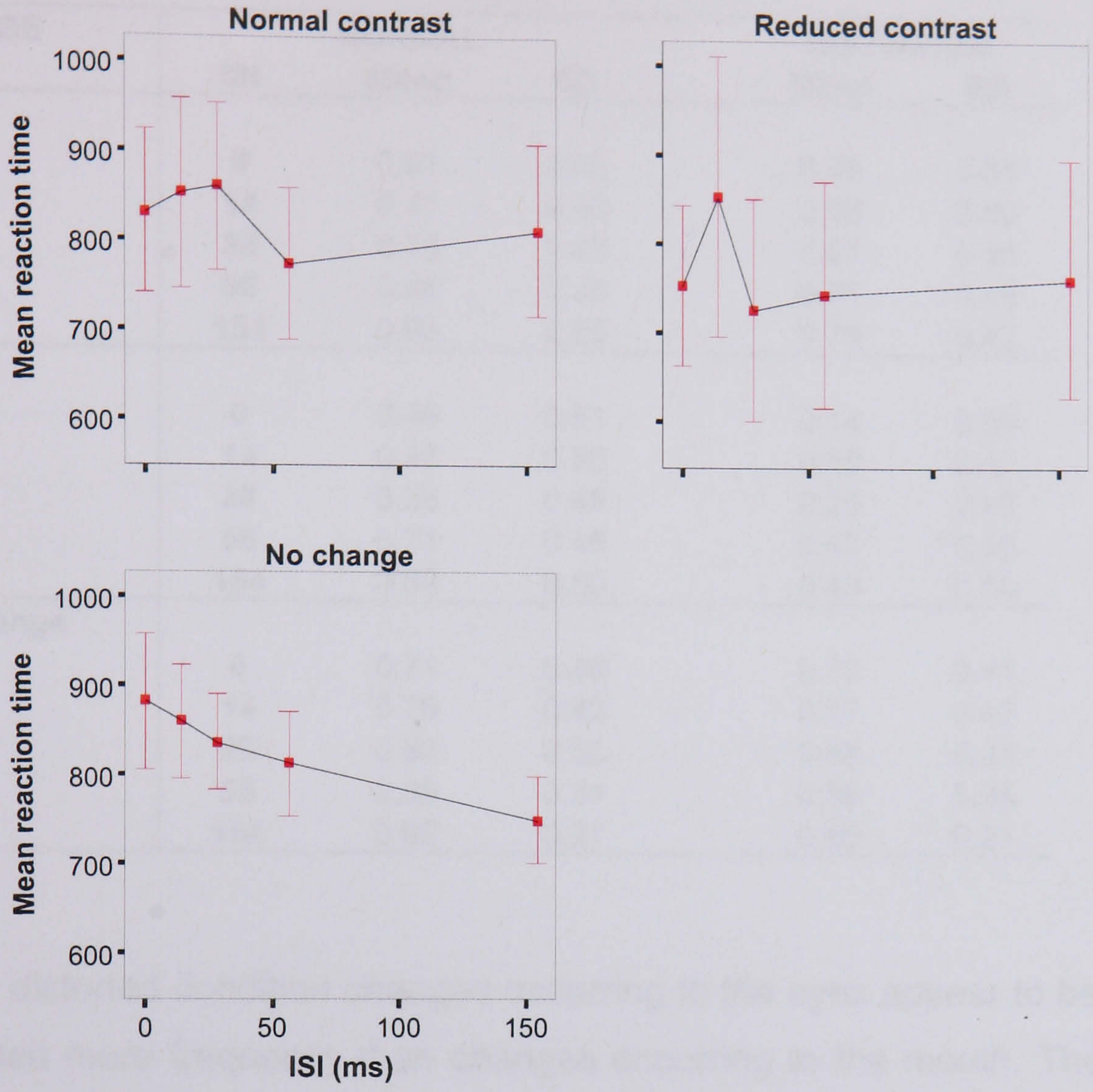


Figure 6.8: The mean reaction times for changes to the eyes in faces with normal eye contrast and eye contrast reduced by 70%. Error bars represent the 95% confidence intervals.

6.3.3 Distorted faces

A repeated measures within-participants 2 x 5 (features x ISI) ANOVA was conducted on the proportion of correct responses for detection of changes within the distorted face condition. The results for changes occurring to the distorted faces were compared between the features and then with the results for the normal faces. Table 6.2 contains the means and standard deviations for each of the two face types, normal and distorted, and for each change condition, change to the eyes, the mouth or no change.

Table 2: The means and standard deviations for proportion of correct responses in the detection of eyes, mouth and no change in normal and distorted faces.

CHANGE		NORMAL		DISTORTED	
	ISI	**Mean**	**SD**	**Mean**	**SD**
Eyes	**0**	0.81	0.40	0.48	0.51
	14	0.71	0.46	0.55	0.50
	28	0.76	0.43	0.67	0.48
	56	0.86	0.35	0.71	0.46
	154	0.93	0.26	0.79	0.42
Mouth					
	0	0.48	0.51	0.14	0.35
	14	0.45	0.50	0.19	0.40
	28	0.38	0.49	0.29	0.46
	56	0.71	0.46	0.43	0.50
	154	0.60	0.50	0.43	0.50
No change					
	0	0.71	0.46	0.79	0.41
	14	0.76	0.43	0.77	0.42
	28	0.88	0.33	0.88	0.33
	56	0.89	0.31	0.86	0.35
	154	0.92	0.27	0.95	0.21

In the distorted condition changes occurring to the eyes appear to be correctly detected more frequently than changes occurring to the mouth. There was a highly significant main effect for the type of feature changed, $F_{1,20} = 16.074$, $p = 0.001$, $\eta^2 = 0.446$ with the eyes being more salient than the mouth . There was also a highly significant main effect of ISI on the mean proportion of correct answers, $F_{4,80} = 4.952$, $p = 0.001$, $\eta^2 = 0.198$, with accuracy increasing with an increase in ISI. There was not a significant interaction between the ISI and the feature changed on the proportion of correct responses, $F_{4,80} = 0.220$, $p = 0.926$, $\eta^2 = 0.011$. Therefore, the features exhibit a distinct difference in saliency in favour of the eyes regardless of this change in ISI. The effect of the distortion was then compared with the results from the normal face conditions. There were significant differences between detection of changes to the mouth and the eyes ($p < 0.05$) at all ISIs except for at 56ms (Appendix D).

Table 2: Paired samples t-test between proportion of correct responses in the change to mouth and change to eyes conditions (*= significant at the 0.05 level; ** = significant at the 0.005 level)

ISI (ms)	t	df	*p*
0	3.162	20	0.005**
14	2.769	20	0.012*
28	2.860	20	0.010*
56	1.862	20	0.077
154	3.101	20	0.006*

A post-hoc paired t-test with Bonferroni's correction was conducted on the data (see Appendix D) and showed that there was a highly significant difference in mean accuracy between ISIs of 0ms and 56s and between 0ms and 154ms (p = 0.01) and there was also a significant difference between ISIs of 14ms and 154ms (p =0.03). This suggests that there is a significant difference in accuracy between the low ISIs (0ms and 14ms) and high ISIs (56ms and 154ms), with greater accuracy at the higher ISIs. The differences between the detection of changes to features in the distorted face condition compared with the normal face condition are examined further in a series of 2 x 5 repeated measures within-participants ANOVAs.

6.3.4 Comparison between the normal faces and the distorted faces

Changes occurring to the eyes and mouth were compared between the two types of face, distorted and normal in a series of 2x5 (feature x ISI) ANOVAs. A comparison between the distorted and normal face condition is presented in Figure 9.

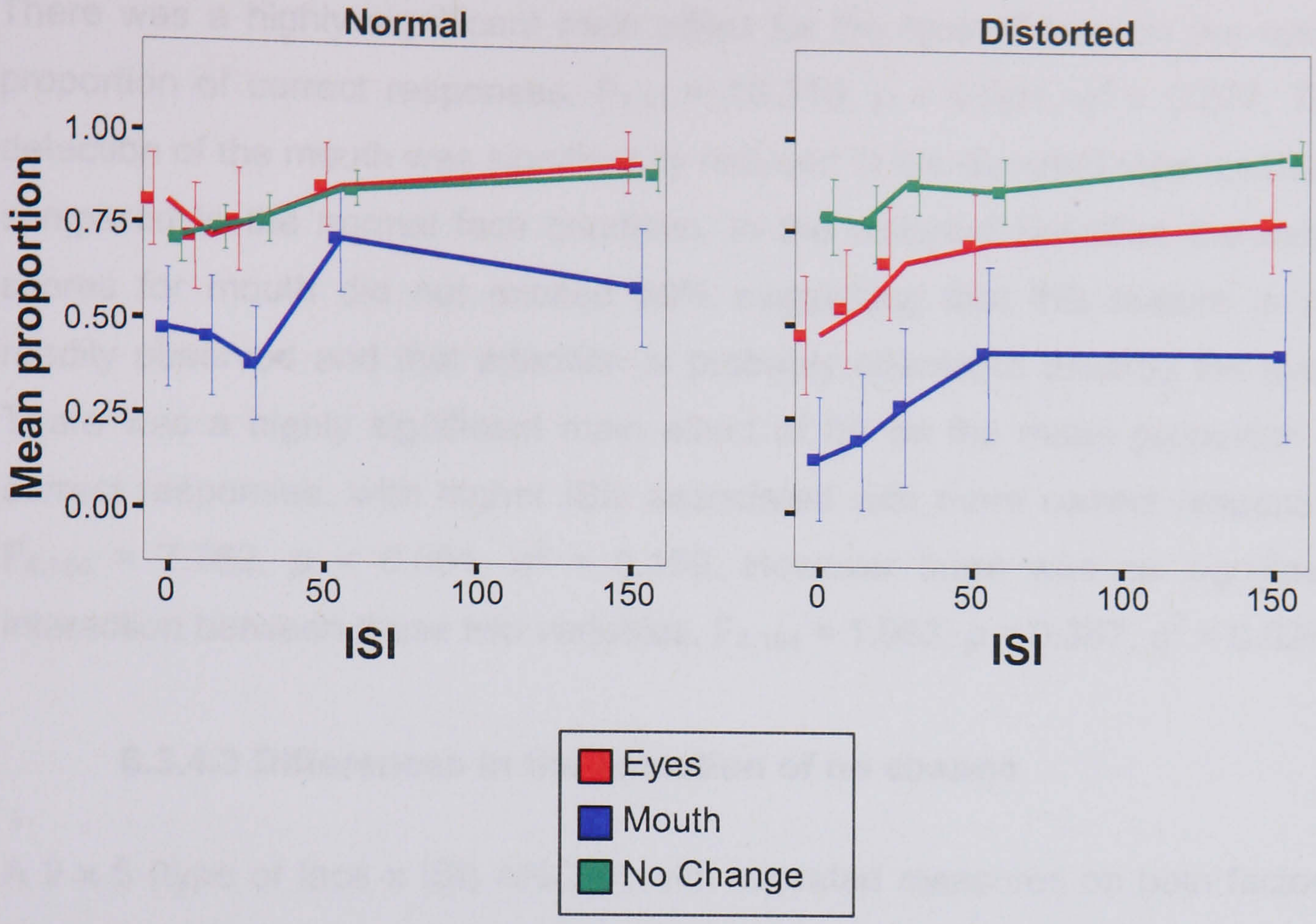


Figure 6.9: A comparison between the mean proportion of correct responses for changes to the eyes and mouth as result of the type of face the feature is presented within, i.e. normal or distorted face. Error bars represent the 95% confidence intervals.

6.3.4.1 Differences in the detection of changes to the eyes

A 2 x 5 (type of face x ISI) ANOVA with repeated measures on both factors was conducted on the correct responses for the eye change condition. There was a significant main effect of ISI on the mean proportion of correct scores for both the distorted and normal faces, $F_{4,164} = 4.028$, $p = 0.004$, $\eta^2 = 0.089$. There was also a significant main effect for the type of face, $F_{1,41} = 13.581$, $p = 0.001$, $\eta^2 = 0.249$. The eyes were thus detected more frequently within the normal face configuration. However, there is no interaction between the ISI and the type of face on the proportion of correct responses, $F_{4,164} = 1.170$, $p = 0.326$, $\eta^2 = 0.028$.

6.3.4.2 Differences in the detection of changes to the mouth

A 2 x 5 (type of face x ISI) ANOVA with repeated measures on both factors was conducted on the correct responses for the mouth change condition.

There was a highly significant main effect for the type of face on the mean proportion of correct responses, $F_{1,41} = 15.713$, $p < 0.001$, $\eta^2 = 0.277$. The detection of the mouth was significantly reduced in the distorted face condition compared to the normal face condition. In the distorted condition the mean scores for mouth did not exceed 50% suggesting that this feature is not readily observed and that attention is probably orientated towards the eyes. There was a highly significant main effect of ISI on the mean proportion of correct responses, with higher ISIs associated with more correct responses $F_{4,164} = 7.762$, $p < 0.001$, $\eta^2 = 0.159$. However there was no significant interaction between these two variables, $F_{4,164} = 1.082$, $p = 0.367$, $\eta^2 = 0.026$.

6.3.4.3 Differences in the detection of no change

A 2 x 5 (type of face x ISI) ANOVA with repeated measures on both factors, i.e. type of face, was conducted on the correct responses for the no change condition. There was no main effect for the type of face, $F_{1,41} = 1.402$, $p = 0.243$, $\eta^2 = 0.033$. This suggests that in both types of face the no change condition was detected equally often. There was a highly significant main effect of ISI on the mean proportion of correct responses, $F_{4,164} = 6.074$, $p < 0.001$, $\eta^2 = 0.129$ with higher ISIs associated with more correct responses. There was no main interaction between the type of face and ISI: $F_{4,164} = 0.652$, $p = 0.626$, $\eta^2 = 0.016$. The 'no change' condition appears to be consistent across both of the conditions.

6.4 Discussion

The significance of considering the face in terms of a pattern defined by a configural triangle is that it allows for the examination of distortions to the face in terms of a disruption of bilateral symmetry. The configural triangle may also provide a directional cue orienting the direction of shifts in attention. This approach to considering facial patterns has been valuable in this experiment. The results of the experiment highlight a clear preference for the detection for changes to the eyes over the mouth, and for the importance of bilateral configuration in detecting change in both the mouth and the eyes.

6.4.1 Saliency of the eyes compared with the mouth

The eyes exhibit stronger saliency with only a marginal masking effect with identification of any changes consistently greater than 70% across all the ISIs. This suggests that either the eyes were not being masked effectively or that the eyes were preferentially attracting attention. However the decline in accuracy at 14ms (see Figure 6.6) suggests that masking is occurring and the results from the contrast experiment suggest that the brightness of the sclera compared with the iris may be preferentially attracting attention.

Identification of changes occurring to the mouth were significantly reduced at ISIs below 56ms suggesting that the mouth was still being processed across this interval. However, the identification of changes to the mouth did not reach the same level of accuracy as in the eye condition even at ISIs greater than 56ms. After 56ms it is suggested that the areas of the cortex associated with face recognition, superior temporal sulcus, inferior occipital gyri, and the fusiform face area, are activated (Kanwisher, McDermott & Chun, 1997; McCarthy et al., 1997; Oram & Perrett, 1992; Perrett et al., 1992; Perrett et al., 1985; Sergent, Otha & MacDonald, 1992; Seeck et al., 1997). Therefore the role of the mouth in this within the process of face recognition may be minimal. The eyes are therefore suggested as being the primary feature used in the early identification of facial stimuli.

The higher saliency of the eyes within early visual processes as compared with that of the mouth could suggest that the eyes represent the dominant feature in the configuration of facial properties. The repeated pattern of the eyes provide redundancy of information that could result in greater saliency and increase the chances of change detection. However, as suggested by the configural triangle model (Figure 6.1) the eyes are also a feature that is positioned towards the upper end of the face. Therefore, they might represent the initial position of the focus of attention and reflect a perceptual bias in scanning objects from top to bottom. Potential hemifield biases in the early visual perception of patterns are investigated further in Chapter 7.

6.4.2 The effects of reducing eye contrast

Reducing the contrast of the eyes resulted in a decrease in the mean proportion of correct answers compared to faces in which the eye contrast had not been manipulated. This suggests that the eye contrast is important in the saliency of the eyes as a facial feature. However, despite a reduction in contrast the average scores for detection of changes to the eyes with reduced contrast were still predominantly higher than the scores for faces in which the mouth was changed. This suggests that either the positional properties of the eyes, i.e. as the top edge of a configural triangle, or the approximate repeated nature of the eyes remain an important factor in their saliency. The contrast might enhance the apparency of the eyes and may aid the rapid detection of redundant configural and repeated information.

6.4.3 The effects of distortion

The effects of distortion and the misalignment of the line of reflective symmetry, as inferred by the nose, with the triangular positions inferred by the position of the eyes and the mouth, appears to result in a reduction in saliency for both the eyes and the mouth. In the distorted condition there is a significant difference in favour of detecting changes to the eyes however this effect is reduced compared to that of the normal face condition (Figure 6.9). The distortion of the face appears to reduce the saliency of the features in general and therefore may suggest that in this condition the features are being processed in a serially suggests as opposed to configural whole in the normal condition. However, the lack of a significant difference between the normal and distorted face in the detection a no change suggest that this factor was no affected by the change in configuration. The high level accuracy for the no change condition in the distorted face compared with changes to eyes or mouth suggests that the masking image increases uncertainty in the participants' responses.

6.4.4 The implications of test of pattern type on face detection

Repetition was suggested (Chapter 5) as being a particularly salient type of symmetry at early ISIs (0ms) and reflection a particularly salient pattern type at later ISIs (>96ms). Patterns that possessed both repetition and reflection were observed as benefiting from the same advantage as repetition at the early ISIs and reflection at the later ISIs (Chapter 5). Applying this to the perception of facial patterns the eyes can be considered to possess both repeated elements and are reflected bisymmetrically across the face and hence will benefit from such pattern saliency.

One issue that would require further investigation is that of a perceptual bias towards the top of a visual stimulus and the possibility of a hemispheric/ visual field bias towards different areas of an image. If there is a hemispheric bias towards one particular visual hemifield then repeated stimuli might show a perceptual advantage in change detection tasks. The eyes in facial patterns provide such redundant information and hence may benefit in this way. However, if there is a top to bottom bias in the perception of an image then there may also be an advantage for eye detection in the processing of facial patterns. These issues of hemispheric and perceptual field biases in the detection of patterns are further explored in the experiments in Chapter 7.

Chapter 7: What spatial properties of a pattern capture visual attention?

7.1 Introduction

The evidence from the backward masking experiments (Chapters 5 & 6) suggests an early visual bias for patterns containing reflective symmetry and also an early visual bias for the eyes and feature configuration as salient features in face detection. However the results of the abstract pattern masking experiment do not indicate which areas of the image are capturing attention. Comments made on the post-experimental questionnaires for the two backward masking experiments indicate a reported bias in attention towards the top left corner for the checkerboard stimuli and the left eye in the face stimuli. In the following sections these biases are investigated further.

In the backward masking experiments there is no time for conscious saccadic eye movements and therefore the initial component identified within a target stimulus could prove essential in its later identification. In this section hemispheric effects, and in particular the effects of information presented to different hemifields on the early visual processing of patterns and faces, are discussed. Evidence from neonates is discussed to emphasise the development of visual strategies and the use of subcortical processing to orientate attention in early vision. In the experiments presented in this chapter the differences in the saliency of different areas of the stimulus were investigated using the backward masking methodology.

7.2 Hemispheric differences in visual processing

The ability to process visual information is not equal in the left and right cerebral hemispheres. Instead, each cerebral hemisphere appears to specialise in the processing of different components of the visual scene. At a basic level the segregation of visual information can be noted at a pre cortical level. Information that is detected in the left visual field (LVF) is conducted along the optic nerves though the optic chiasm to the primary visual area of the right hemisphere of the neocortex. Conversely information that is picked up in the right visual field (RVF) is transmitted to the primary visual areas of the left cerebral hemisphere (Fahle, 2003; Gazzaniga, 2000; Gazzaniga et al., 1996). This suggests that each hemisphere will have a bias towards one particular hemifield and that both hemispheres are necessary for the accurate depiction of the visual world. However, at later stages of visual processing, i.e. post V1, the right hemisphere appears to exhibit vigilance responses to both of the visual hemifields (Corbetta et al., 1993).

To achieve an accurate depiction of the visual world, communication between the hemispheres is essential. This is accomplished via the corpus callosum. The corpus callosum is a collection of nerve fibres that run contralaterally connecting the two hemispheres of the neocortex. Many studies into hemispheric biases utilise the separation of the visual field into two distinct hemifields by presenting a target to a single hemifield and recording participant responses (Hubner, 1998; Robertson et al., 1993; van Kleeck, 1989). However in healthy adults this can be confounded by inter-hemispheric interactions via the corpus callosum and a lack of cortical specificity in terms of the function that is being examined.

Further evidence of hemispheric specificity is obtained from patients that possess lesions to localised areas of the neocortex affecting only one function (Volpe, Ledoux, & Gazzaniga, 2000). In the following sections hemispheric differences in relation to visual and pattern perception are discussed. These differences include processing of stimuli at a global and local level, the classification of stimuli, face perception and spatial attention.

7.3 Left hemisphere local and right hemisphere global pattern elements

It has been suggested that there is differential processing of global and local stimulus properties between the two hemispheres. The global properties of a stimulus are those that define the overall shape of the visual object, while local properties are those of the features, or surface texture of the object. This is of importance with regard to pattern perception as it has been suggested that reflective symmetry is perceived as a global property while repetition is perceived as a serially processed background texture (Baylis & Driver, 1994).

Experiments that are used in the identification of local and global image properties frequently utilise nested stimuli (Figure 7.1) which can be distinguished in terms of the local component letters or the global letter formed by the arrangement of these components (Delis, Robertson, & Efron, 1986; Hubner, 1998; Navon, 1981; Navon, 1977).

aaaaaa
a
aaaaaa
a
aaaaaa

Figure 7.1: example of a nested letter stimulus used in global and local perception experiments

It has been observed that damage to the right temporo-parietal lobe results in an over focusing on the local features of a scene suggesting that the left hemisphere is dominant in the perception of local elements (Robertson & Lamb, 1991; Delis, Robertson, & Efron, 1986). Conversely, damage to the left hemisphere results in bias towards the global perception of objects suggesting right hemisphere dominance for perceiving global features (; Delis, Robertson, & Efron, 1986).

Hubner (1998) provided a summary of evidence that support the suggestion of hemispheric differences in local and global processing. According to this evidence local processing would primarily occur in the left hemisphere and global processing in the right hemisphere. By this rationale, global images should be more readily perceived when presented in the LVF and local aspects of an image more readily identified in the RVF. However as Hubner suggests, the evidence in support of this is fairly evenly split (Hubner, 1998; Robertson et al., 1993, in support and Boles & Karner, 1996; van Kleeck, 1989, against). Although van Kleeck found no evidence in his experiments to support a local versus global hemispheric split, in a meta-analysis of previous studies he did conclude that evidence did exist to support the left hemisphere/ local and right hemisphere/ global hypothesis. Some of the differences in significance for these experiments could be due to an over simplification of the role of the relationship between the visual hemifields and the individual hemispheres.

Evidence from patients with damage to the left hemisphere (Heilman et al., 1993) and from PET scans of healthy patients (Corbetta et al., 1993) suggests that for either visual hemifield the right parietal cortex is active during vigilance. However, if there is damage to the right parietal areas then deficits in the perception of the LVF become apparent. Therefore the right hemisphere plays a more global role in the perception of visual objects across both hemifields while the left hemisphere is more specifically attuned to one visual hemifield and serial processing of local elements. The dominance of the right hemisphere in visual processing post primary visual areas could therefore reduce the distinction between the hemifields in local and global detection tasks.

Fecteau et al. (2000) provided additional evidence in support of the hemispheric difference in global and local processing. In their experiments participants had to either detect the presence or position of a target within a display. Fecteau et al. observed that there was right hemisphere superiority in the detection of the targets however the left hemisphere was dominant in identifying the location of the target. Therefore the right hemisphere was the primary hemisphere in detecting the global properties of the scene, i.e. the presence of a target, while the specific local properties, i.e. where the target is situated, favoured the left hemisphere.

In terms of pattern perception this could suggest that global properties such as reflective symmetry that have a global form, would be favoured by right hemispheric functions with information picked up from across both visual hemifields. Meanwhile repetition would be favoured by the right visual field and left hemispheric functions, as the individual local elements may need to be identified sequentially in order to accurately detect a pattern. Similar arguments have been put forward by Atchley and Atchley (1998) who provided evidence of a right hemisphere specialisation in applying perceptual principles that lead to object formation, while the left hemisphere processes information about the individual features of an object. The global versus local argument can also be applied to the perception of faces in terms of either configural or featural properties. The configural properties may be processed globally as per reflective symmetry while the featural elements may be processed in a similar manner to repetitive textual properties and therefore could be predominantly perceived within the left and right visual field respectively.

7.4 Left hemisphere classification and right hemisphere spatial

Similar to the global versus local differentiation the functions of the two hemispheres can be divided up into a RVF, LH, advantage when categorising abstract stimuli (Volpe et al., 2000; Funnell & Gazzaniga, 2000; Marsolek, 1995) and RH dominance for spatial properties (Funnell, Corballis, & Gazzaniga, 1999; Umilta, Bagnara & Simion, 1978). In many respects there is little distinction between this terminology and that of the global versus local biases.

Volpe et al (2000) examined visual extinction within the LVF of patients with lesions in the right parieto-occipital cortex. The presentation of an object anywhere within the visual field resulted in an accurate description, however when two objects were presented, one in each visual hemifield, only the object in the RVF could be identified. However if the patient was then asked to respond to the object in a same or different scenario, the patient could tell if the two objects were the same despite not being able to identify the one presented in the LVF. In two of the patients tested they were aware of a presence in the LVF but unable to identify what exactly it was, the other two patients tested were totally unaware of the objects in the LVF. Volpe et al. concluded that the objects were being perceived at a subconscious, non-verbal level and information from the LVF was not made available to the left hemisphere for classification. This would suggest that within an intact brain that the right parietal cortex provides information on the properties of objects in the LVF that are subsequently processed further within the LH at which point the image can be described at a conscious level.

Damage or surgical severing of the corpus callosum inhibits inter-hemisphere communication, isolating the functions of each neocortical hemisphere (Gazzaniga, 2000; Sperry, 1968; Zaidel & Sperry, 1977). Patients that possess this condition are referred to as split-brain patients and provide valuable case studies into the individual functions of each hemisphere. Evidence from split-brain patients suggest that the right hemisphere has superiority over the left hemisphere in terms of its ability to shift the focus of attention in response to gaze direction thus utilising spatial information (Kingstone et al., 2000). Kingstone et al. identified areas in the right hemisphere that were crucial to this response, they were the face processing areas of the superior temporal sulcus, areas of the infero-temporal and the parietal areas involved in the spatial orientation of attention. This highlights an orienting of attention via the right hemisphere vital in distinguishing intentionality and expressions in faces.

In a forced choice experiment where participants have to identify whether two sequentially presented stimuli were the same or different, there was a RVF advantage in terms of reaction times for simple geometric figures, e.g. squares and triangles, and a LVF advantage for complex geometric shapes, e.g. decahedrons (Umilta, Bagnara & Simion, 1978). Umilta et al. suggested that this provided evidence of the discrimination of single features in the LVF and spatial/ global properties in the RVF. This could suggest that within the LH/ RVF there is a bias towards serial processes, therefore simple shapes are discriminated more rapidly, while the RH/ LVF utilises spatial information to determine global stimulus properties. However variations in these findings could be due to the attribution of categories and labels to the frequently encountered simple stimuli (Banich, 2004). The LH is strongly associated with linguistic and categorical function and therefore will have superiority in naming perceived objects. This can be illustrated in that lesions to the left sided angular gyrus are associated with deficits in linguistic functions such as pure alexia (Zihl, 2003). Therefore when examining patterned stimuli hemispheric and perceptual biases could be affected by the attribution of categories directing attention, i.e. more people know what properties constitute a 'square' than the properties that constitute an 'decahedron'.

In patients with split brains, where the corpus callosum has been surgically severed for a variety of reasons (e.g. epilepsy) there is no evidence of activity within the right hemisphere when patients are performing verbal classification tasks (Funnell & Gazzaniga 2000). However visual processing within the left hemisphere was directed towards pattern recognition at the expense of spatial information (Funnell, Corballis, & Gazzaniga, 1999). This suggests that the left hemisphere has become dominant in the language acquisition and classification areas and that the right hemisphere has remained the dominant perceptual area dealing with the rapid processing of spatial information. This suggests that when distinguishing pattern types there is a possibility of participants attempting to classify what they have seen rather than identify it based upon the image properties, i.e. spatial information and contrast boundaries. This could be of particular significance in face perception as the human face is loaded with social and personal information that may utilise both LH classification and RH perceptual dominance.

7.5 Right hemisphere dominance in face perception

In the discussion so far, regions of the LH have been associated with conscious and logical thought while regions of the RH have been associated with more rapid global processes. Face perception is a function that can be perceived as being processed in both of these ways, either in terms of the conscious process of face identification and the global process of identifying the configural properties of the features. If the areas for face perception in the right hemisphere are lost, identification is only possible by serially matching features to the faces (Carter, 1998). Disorders relating to orientation, spatial attention and face perception have been predominantly associated with the right hemisphere and LVF (de Renzi, 1982; Gazzaniga & Smylie, 1991; Karnath et al., 1998; Vallar & Perani, 1986). However facial stimuli can be broken down into global and local properties, with the facial configuration or overall shape of the face representing the global properties and the individual features representing the local properties. Therefore it would be expected that there are similar hemispheric differences in face perception as with other abstract stimuli.

As discussed in chapter 3, inverting the faces disrupts the global properties of facial stimuli and recognition. When inverted faces were presented separately to the LVF and RVF, recognition of faces presented to the LVF was affected more by inversion than those presented to the RVF (Bruyer & Velger, 1981; Young & Bion, 1981; Young 1984). This suggests that when processing the configural properties of the face there is a dominance of the right hemisphere and LVF. In studies of the RVF and face perception it has been shown that there is left hemisphere dominance for the categorisation and naming of facial stimuli (Sergent, 1985). The division of labour in facial processing with a general right hemisphere dominance for recognition and left hemisphere bias for classification would allow for both the rapid recognition of an individual's face and the serial processing of their features that would be vital in judging a fellow group member's mood or intentions. However, there has been identified a RH advantage for the perception of emotional expression (Nelson, 2001). In an ERP study (Pizzagalli, Regard & Lehmann, 1999) the presentation of emotional faces elicited responses 80-116 ms after right hemisphere and 104-160 ms after left hemisphere stimulation. This suggests that the right hemisphere may be dominant in making rapid judgements about affective stimuli.

Several studies on both adults and infants suggest that there is a right hemisphere bias towards configurational aspects of face processing (Allison et al., 1994; Catherwood et al., 2003a, 2003b; Catherwood et al 2001, de Schoenen et al., 1993). In experiments on infants with an average age of 24 weeks there was an initial bias towards the right hemisphere and LVF, for the processing of facial configuration (this was done by presenting faces upside down and right way up to the infants) followed by a shift of focus from spatial to the chromatic attributes (Catherwood et al., 2003). This supports theories of a right hemisphere and global pattern dominance in face processing. Similarly in a study of infants aged between 4 months old and 10 months old, there was a right hemisphere, LVF, advantage for identifying faces at around 5 months old, the age at which children can identify faces from photographs (de Schonen & Mathivet, 1990).

Hyper-familiarity is the inability to accurately determine the familiarity of a strangers face, i.e. all people encountered are perceived as being familiar. In the case study of a 21-year-old woman who suffered from hyper familiarity as a result of damage to the temporo-occipital areas in the left hemisphere, it has been shown that left hemisphere is vital in the accurate classification of faces (Vuilleumier et al., 2003). Unlike in prosopagnosia where there is an inability to recognise faces and therefore all faces appear to be unknown to the patient, the 21-year-old woman could identify the faces of people she knew, however her judgements about strangers were not as good. When presented with an unknown face the patient would believe it to be a familiar face in 80% of trials. Vuillemier et al. (2003) suggest that this hyper-familiarity is a result of over activation of the right hemisphere and a bias towards rapid global processing combined with a lack of communication between the two hemispheres. Without the left hemisphere directing attention to specific local elements in the face and therefore specific character traits, the patient was unable to correctly attribute emotion and familiarity to many of the faces presented to her. However, Ernest (1997) suggests that face recognition tasks are not necessarily a good predictor of right hemisphere superiority in face perception and that verbal fluency was probably a more significant influence. This evidence supports that of Vuillemier et al. (2003) in that it shows that there is an important role to be played by the left hemisphere in such tasks and that face identification is not exclusively a right hemisphere process even if the visual processing of the faces can be considered to be primarily a right hemisphere function.

Sergent (1996) notes that in some studies a bias towards left hemisphere perception can be obtained by the use of only a few target faces that are repeated throughout the trials, this results in a greater role for identification and classification, i.e. functional properties that can be associated with the LH dominance. Therefore results on hemispheric biases noted in face perception tasks have to be interpreted in terms of not only the configural properties of the stimulus but also the social context and emotional qualities of the stimulus.

The evidence presented in this section suggests that the RH functions are dominant in the comprehension of upright face stimuli while LH functions are dominant in the sequential processing and classification of faces (Sergent, 1996). However, optimal processing of faces is reliant on interactions between both of the cerebral hemispheres (Vuillemier et al., 2003). This face processing asymmetry is not an exclusively human trait. Studies of other primate species suggest that there is also lateralisation of function with respect to face processing within the cortex of the rhesus macaque (Hamilton & Vermeire, 1988; Vermeire & Hamilton, 1998). The right hemisphere was shown to be dominant in the detection of the faces of other monkeys. This suggests that the lateralisation of the cortex is probably the result of evolutionary pressures to process compound signals from fellow group members (Guilford & Dawkins, 1991). However the generation of these compound signals will also be under the control of specific cortical and possibly hemispheric functions, and therefore could be influenced by perceptual biases. One such bias has been identified for the signalling of emotion in the left hand side of the face (RVF).

7.6 Left side of face in emotion

Sackeim, Gur and Saucy (1978) presented faces to participants that comprised of either a face constructed from a reflection of the right hand side or left hand side of the face. The participants had to rate how intense the emotional expressions were for each type of stimulus. The participants rated the composite made up of two left hand sides of the face as expressing more emotion. The side of the face expressing the strongest emotion, i.e. the left side, will be presented in the RVF of the observer.

This may create a dilemma as evidence from brain asymmetry studies suggest that processes occuring in the RH of the brain are dominant in face recognition and the detection of emotional expression (de Renzi 1982; de Schonen & Mathivet, 1990; Vallar & Perani, 1986; Gazzaniga & Smylie, 1983; Karnath et al., 1998). Conversely, the presentation of emotional expression in the RVF may provide an advantage, as left hemisphere functions have been shown to exhibit dominance in the categorisation and naming of facial stimuli

(Sergent, 1985). However the RH is dominant in creating the emotional expressions in the left hand side of the face and this apparent dilemma between expression and perception could simply be the result of a prior expression process evolving before hemispheric differentiation for face perception.

Sackeim et al (1978) argue that this discrepancy might have evolved to allow for compensation for the differences in the visual fields and face perception. This is only true if the person expressing the emotion were standing directly in front of the viewer, from greater distances this effect would become reduced, as the face would be perceived on a more global scale. The models for the composite pictures used in the experiments of Sackeim et al. (1978) were making specific emotional expressions that might therefore be seen as more intense than those experienced naturally in everyday life. However although the results might be amplified by the use of this type of methodology, the experiments do highlight an asymmetry in face perception that could reflect the suggested bias for left hemisphere, RVF, in processing local information, i.e. how the features are arranged or patterned to express emotion.

Hauser & Akre (2001) examined evidence for facial and vocal asymmetries in the expressions of rhesus macaques, *Macacca mulatta*. The results obtained suggested that in both adult and infant macaques that there was a timing delay in the formation of expressions between the two sides of the face. Their studies concluded that there was right hemisphere/ left side bias in the production of facial expressions. These results were not in accord with the emotional valence hypothesis (Davidson, 1995) that suggests that different brain hemispheres, primarily prefrontal areas, might be differentiated in terms of positive/ approach emotions such as happiness and negative/ withdrawal emotions such as sadness. So evidence from both human and non-human primates suggest that there is a definite brain asymmetry in the production of facial expressions, evidence from humans suggest that there is also a perceptual bias towards the left visual field and therefore in conversational behaviour the right visual field (left hand side of the face) would have to compensate in order to be noticed.

Nicolls et al. (1999) examined which side of the face is presented more prominently in portraits. The results suggest a general bias towards the left side of the face in portraiture. In their experiment participants were randomly assigned different portrait conditions, either an emotive condition where they were taking a photo to give to their family before going overseas for a year, or an impassive condition where the participants were trying to present a 'clear thinking' and non emotive face. The results showed a bias towards presenting the left hand side of the face in the emotive condition and a trend towards presenting the right hand side when concealing emotion. This evidence supports that of Sackheim et al. (1978) in that the left hand side of the face appears to be dominant for expressing emotion and social signalling.

These hemispheric biases in both expression generation and general perception could reflect the continued postnatal development processes of the human cortices and an adaptation to the environment that the neonate encounters in early life. However prior to this specialisation it has been suggested there could be a greater reliance on sub-cortical pathways (Bronson, 1974). Similarly when visual processing time is artificially reduced, for example as in masking experiments, then the cortex will be more reliant on sub-cortical processes. To explore this aspect of early visual processing further a brief outline of developmental studies into hemispheric development and alternative visual pathways are discussed.

7.7 Evidence for hemispheric differences and alternative visual pathways from developmental and evolutionary studies

During infancy it is suggested that there is greater cortical lateralisation than in adulthood (Segalowitz & Berge, 1998) and that there are continued age related changes in hemispheric dominance throughout life (Cherry & Hellige, 1999). In the following section the early development of visual processing is discussed with relation to hemispheric differences and sub-cortical processes.

Several arguments for the development of hemispheric differences have been put forward; one such argument is that there is a developmental lag between hemispheres resulting in a differential maturation effect (Corballis, 1989; Geschwind & Galaburda, 1985). In these arguments it is suggested that one hemisphere will have an advantage over the other in terms of function at any one particular time in development, whether it be a right hemisphere advantage for face processing (de Schonen & Mathivet, 1989; de Schonen, Gil de Diaz & Mathivet, 1986) or a left hemisphere advantage for auditory and language functions (Bever, 1975). However this developmental lag argument has been contended by evidence suggesting that at any particular age during development there will be right hemisphere advantages for some functions and left hemisphere advantages for other functions (Thatcher et al., 1987).

Prior to 24 months in age, infants are unable to discriminate differences between images, both abstract shapes (Liegeois & de Schonen, 1997) and schematic faces (Liegeois, Bentejac & de Schonen, 2000) when presented to separate visual hemifields. However infants below 24 months of age were able to discriminate differences if the images were presented unilaterally to only one visual hemifield. The ability to compare visual events between visual hemifields therefore appears be late in development at around the age of 2 years. This late development suggests that although there is hemispheric specialisation (to a degree) at birth, further hemispheric specialisation is required (Liegeois, Bentejac & de Schonen, 2000; Liegeois & de Schonen, 1997). The ability to compare between images presented to different hemifields at this age could be due to changes that occur to the corpus callosum at around this age (Elberger, 1982).

Postnatally the human brain continues to develop in terms of synaptogenesis, the production of new synapses and myelination, an increased in fatty sheath that surrounds neuronal pathways (Johnson, 2000). It has been noted that different areas of the cerebral cortex develop differentially. For example the prefrontal cortex has been shown to take longer to reach maximum synaptic density, approximately one year, when compared with the visual cortex, approximately 4 months postnatal (Huttenlocher, 1990, 1994). This has been suggested as an example of a posterior to anterior development of the cerebral cortex (Huttenlocher, 1990). In infants under 5 weeks of age most cortical activity is in the sensorimotor areas, brainstem and thalamic areas, by

3 months there is an increase in the activity of the parietal, temporal, occipital areas, and basal ganglia. By 6 to 8 months there is an increase in activity in the frontal lobes and in the dorsolateral occipital areas, those areas associated with higher functions and object perception (Chugani et al., 1991; Huttenlocher, 1990; Chugani, Phelps & Mazziota, 1987). As illustrated by PET (positron emission tomography) studies by Chugani et al., (1987) glucose intake in the developing cortex is greater than in the adult brain, and approximately coincides with a peak in the number of synapses. However, as the brain develops in early childhood there is a progressive loss of neurons (Hottenlocher, 1990). This combined with continued myelination throughout life reflects a refining and focusing of the cortex into its specialist functional areas.

Growing a large brain is a costly process for any animal and this too will have implications on the development and subsequent use of the visual system postnatally. Due to constraints on the size of the birth canal and effects on locomotion human infants are born at an early stage of development while the brain is not fully formed. Compared to other primate species, the human infant is born prematurely, while for most primate species the rate of post-natal brain growth, in terms of the expansion of existing neurons and the addition of glial cells is minimal after birth, in humans brain growth has been show to continue for approximately a year after birth (Barrett, Dunbar & Lycett, 2001; Deacon, 1997; Smith & Tompkins, 1995; Harvey, Martin & Clutton-Brock, 1987). This is reflected in the poor visual acuity and relatively under developed cognitive skills of the human neonate during the first year of life. Therefore the continued growth in terms of myelination and synaptogenesis plus the lack of a fully formed corpus callosum could result in greater hemispheric specialisation of the human neonate brain during development. This could also suggest a significant reliance on more basic sub-cortical visual processes during the first few months after birth. However, this is not to say that the human neonate is born *tabula rasa*, i.e. with a blank mind, as there is considerable evidence to suggest that newborn infants possess most basic perceptual and cognitive functions, i.e. attention, memory, classification and object constancy (Karmiloff-Smith, 1992; Slater, Mattock & Brown, 1990).

Retinal ganglion cells not only project to the higher visual areas of the LGN and the striate cortex, retinal ganglion axons also project to the superior colliculus a dorsal area of the mid brain. At birth the subcortical structures appear to be more advanced in development than those of the higher brain functions (Bronson, 1974; Chugani et al., 1987). In particular the superior colliculus is involved in saccadic eye movement and head orientation, and has been suggested as a possible alternative visual pathway for patients that exhibit blindsight due to scotomas in the primary visual cortex (Cowey & Stoerig, 1993) and in the visual processing of the neonate (Bronson, 1974, 1982). When infants focus on the periphery of images it has been suggested that this could be due to a lack of myelination and development of the occipital cortex and reduced inter-hemispheric communication as the corpus callosum maturates (Johnson, 1990; Maurer & Salaptek, 1976). This would result on a relatively greater role for the highly developed sub-cortical structures. However, these subcortical pathways do not explain colour vision, size constancy and shape constancy within 3-dimensional space, all properties that are present within the newborn infant (Slater & Morison, 1985; Slater, Mattock, & Brown, 1990). Therefore a reliance on subcortical processes in the neonate can only provide a partial explanation for infant visual behaviour.

Maurer and Salaptek (1976) looked at how 1-month-old and 2-month-old infants scan faces using corneal photography to track the eye movements. They found that the 1-month-old infants would initially look at the perimeter of the faces, primarily the hairline and the chin. The 2-month-old infants would initially look at the eyes first. They suggest that this could be because 2 month old infants are more likely to look inside an object and at the area of highest contrast first or attribute special significance to faces and eyes. This also reflects a switch from the use of sub-cortical visual pathways towards cortical visual pathways.

The retina of 8-day-old infants still exhibit deficits in macular development, the area associated with high acuity cone based vision. Therefore Abramov et al. (1982) suggest that the neonate's vision is biased towards extrafoveal vision. With the mid brain being largely developed at birth (Johnson 1990) and the

LGN doubling in volume during the first 6 months, this could suggest a relative dominance of the sub-cortical pathways via the superior colliculus at birth.

This means that at shortly after birth the cortical structures and visual pathways in the cerebral areas are not fully developed for specialised face perception and object identification, however evidence from Goren, Sarty and Wu (1975) and Johnson et al. (1991) show that even directly after birth there is a preference in infants for tracking objects that contain face like stimuli. This bias could be due to the presence of a high contrast features attracting the attention of low acuity subcortical visual perception (Johnson & Morton 1991). However, there are strong arguments for the existence of basic cortical function in newborns (Maurer & Lewis 1979; Posner & Rothbart, 1980; Slater & Morison, 1985; Slater, Mattock & Brown, 1990). These basic cortical functions such as attention, memory and object constancy are essential tools for the infant to mould the synaptic organisation of the cortex by experience. However, as activity in the cortical areas will lag behind maturation (Chugani et al., 1987) there may be apparent deficits and reliance on sub-cortical structures during the first few weeks of life. Similarly in adults when access to higher brain functions is interrupted there may be a reliance on these sub-cortical pathways. It is therefore necessary to provide a brief outline of the subcortical visual pathways.

This sub-cortical pathway with a bias towards extrafoveal vision would provide an automatic orientation of the visual system to peripheral areas of an image, when combined with the evidence from hemispheric studies this provides a possible explanation for hemifield biases in visual perception, in that the dominant hemisphere will pick up information from the periphery of the respective visual field. It would therefore be expected that during backward masking experiments there would be a bias towards peripheral vision and greater accuracy in detecting the edges of a stimuli at early ISIs. The initial location of this edge perception would be expected to be towards the LVF due to the right hemisphere dominance in visual recognition and global perception and insufficient processing time for complex categorisation of the stimuli.

7.8 Summary

The right hemisphere, LVF, is dominant in the processing of spatial stimuli and the superior colliculus orientates attention towards the periphery of images during early visual perception. In order to investigate this the backward masking experiments were repeated with changes to either the upper, lower, left or right half of the images for the abstract stimuli and either the left or right eye for the facial stimuli. The expectation is that changes made to the LVF, i.e. the left half of a target image, will be identified more accurately at short ISIs than those with changes in the RVF. Similarly as suggested in Chapter 1 (Page) image orientation also plays a significant role and this is explored in the random checkerboard stimuli by presenting random changes in the upper and lower visual hemifields. It is expected in this condition that there will be a top-bottom bias in accuracy.

7.9 Experiment 1: Change detection for different areas of abstract patterns

The first experiment examines the biases in perceptions for different hemifields of a checkerboard target stimuli. The target patterns consisted of either repeated, reflected or random checkerboard patterns. The aim of this experiment was to see if there were general hemispheric biases in terms of the orienting of first vision and if these biases are common for both types of symmetry. The dependent variable in this set of experiments is that of accuracy in the detection of changes, the accuracy is measured in terms of the proportion of correct responses to each condition.

7.9.1 Methods

7.9.1.1 Participants

Nine participants, four male and five female were obtained from an opportunistic sample at the University of Gloucestershire. All participants were offered £5 compensation for their time regardless of the number of trials they completed. All participants were aged between 19 and 40 years old all and had healthy or corrected vision. One participant withdrew after the practice trials, and one participant withdrew halfway through the experiment, the other 7 completed the whole experiment. All participants provided their written informed consent prior to taking part in the experiment and were free to leave the experiment at any time.

7.9.1.2 Apparatus

The experiment was run on a Viglen 500MHz computer with a Pentium 4 processor, the screen used was a Viglen 17" TFT multimedia monitor with a refresh rate of 75.0059 Hz and a refresh duration of approximately 13.333ms. Prior to each experiment the computer refresh rate was tested using a Refresh Clock experiment (E-Prime, 2002). The screen area was 800 x 600 pixels and the display in 16-bit colour. The experimental stimuli were created using Adobe Photoshop CS version: 8. The experiment was constructed using E-Prime psychology software version 1 (2002).

To reduce after-image effect a grey background colour was chosen for the screen and the brightness set to 29% and the contrast 70% on the monitor settings. The experimental area was 2.35m x 2.75m with a blacked out background and the ambient light maintained around 0.9 Lux to reduce glare. Participants were seated between 60cm and 70cm from the display and asked to make themselves as comfortable as possible before the experiment started.

7.9.1.3 Stimuli

The stimuli used were based on the same checkerboard stimuli used in the previous masking experiments (Chapter 5 & Appendix A). The stimuli were manipulated by randomisation of one half of the pattern, either on the left hand side or the right hand side or to the top half or bottom half of the stimuli. For the reflective symmetry condition the randomisation would occur across the line of reflection so as not to present a purely random picture but leave some of the symmetry present for comparison between conditions. In order to do this the original image has to be rotated by 90 degrees to alter the orientation of the reflective axis and then the appropriate half of the image replaced with a random image (Figure 7.2).

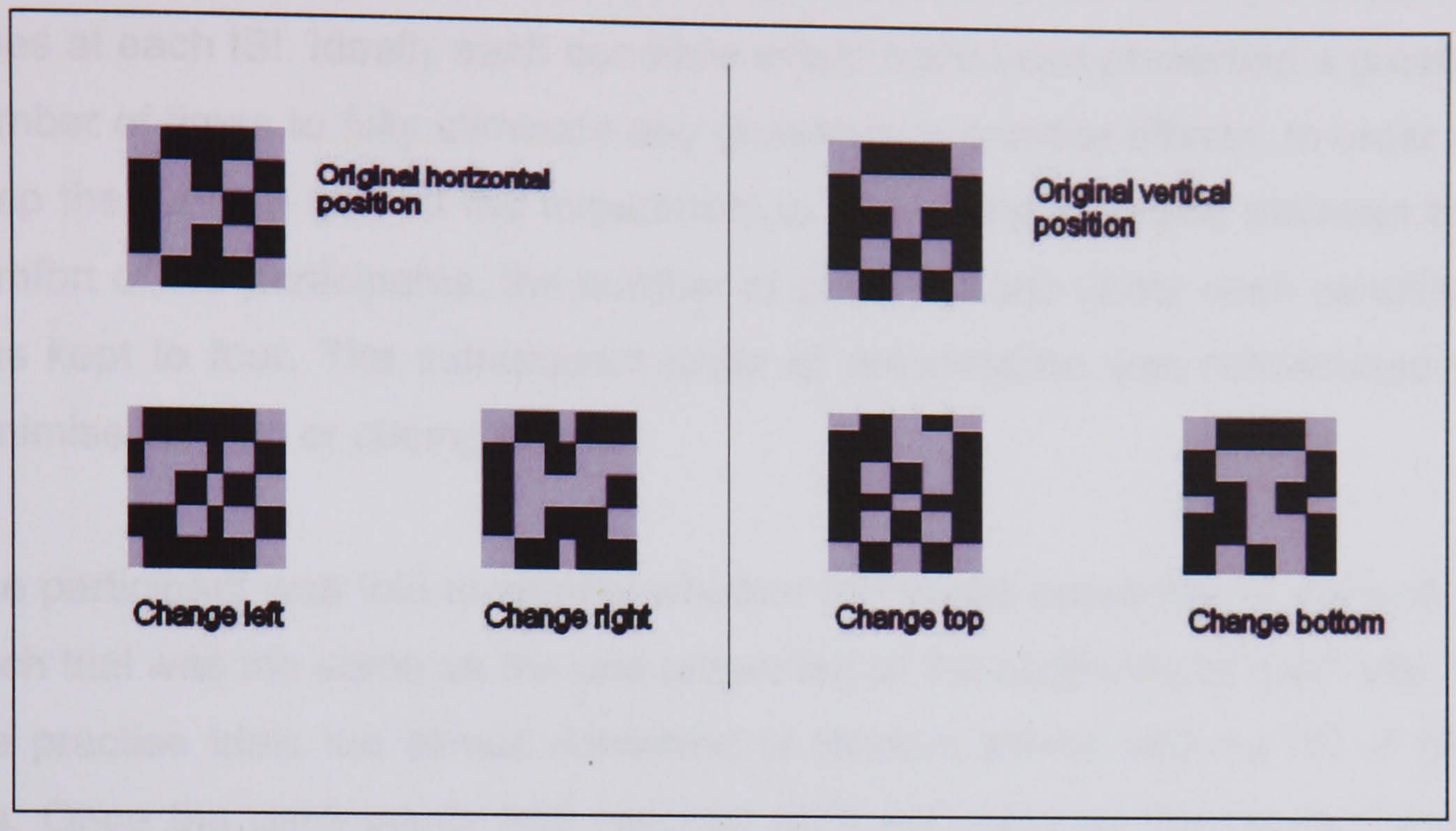


Figure 7.2: Examples of the stimuli for the reflection condition. The original stimulus is rotated so as to preserve the line of symmetry in all change conditions. In each change condition one half of the original stimulus is swapped with a random half.

The target patterns were created from 4 different repeated and reflected patterns. This was to minimise the number of trials that a participant would have to perform. From these four basic patterns 16 different repeated stimuli and 16 different reflective symmetry stimuli were created. This was so that all 4 hemifields could be equally represented in the four basic repeated and reflected patterns. In the practice trials random patterns were used over a longer duration ISI (500 ms) as per the general methodology (Chapter 4). The stimuli were presented in the middle of the display at a size of 21cm x 21cm and an approximate visual angle of 18°.

7.9.1.4 Procedure

The participants were seated in the experimental area. The researcher remained with the participant while they worked through the instructions but left as soon as the practise trials started so as not to distract the participant.

The masking procedure described in the general methodology chapter was used. The ISIs used were the same as those used in the checkerboard abstract pattern experiment (Chapter 5: section 5.2.4), these were 0, 14, 48, 96, 208 ms. The experiment took approximately 30 to 40 minutes and consisted of 440 main trials. Each condition was presented to the participant 4 times at each ISI. Ideally each condition would have been presented a greater number of times to fully eliminate any guessing or practice effects. In order to keep the running time of the experiment to below one hour and maintain the comfort of the participants, the number of presentations under each condition was kept to four. The subsequent order of presentation was randomised to minimise priming or cueing effects.

The participant was told to identify whether the image presented at the end of each trial was the same as the one presented at the beginning of each trial. In the practise trials the stimuli consisted of random stimuli with an ISI of 500 ms. Once the participants had reached 80% accuracy on the practice trials they were able to continue to the main trials, the practise run consisted of 20 trials per cycle, all participants obtained 80% after one cycle of practise trials. Every ten minutes the participant was given the opportunity to take a short break from the experiment in order to prevent fatigue. Once the trials were completed, the participant was offered a chance to provide feedback on the experiment and was fully debriefed.

The dependent variable measured was the accuracy, i.e. the proportion of correct responses under each condition. Due to the small sample size non-parametric tests were used to analyse the results and any trends identified from graphs of the mean proportion correct for each condition.

7.9.2 Results of experiment 1

As shown in Figure 7.3, there is a trend across all ISIs for greater accuracy in spotting changes that occur to the left and upper hemifields of the target stimuli. The following trends are for all symmetries grouped together. There is a visible trend towards a bias towards spotting changes in the LVF more frequently than changes in the RVF. This was only significant at ISIs of 96ms (Figure 7.4, Table 7.1).

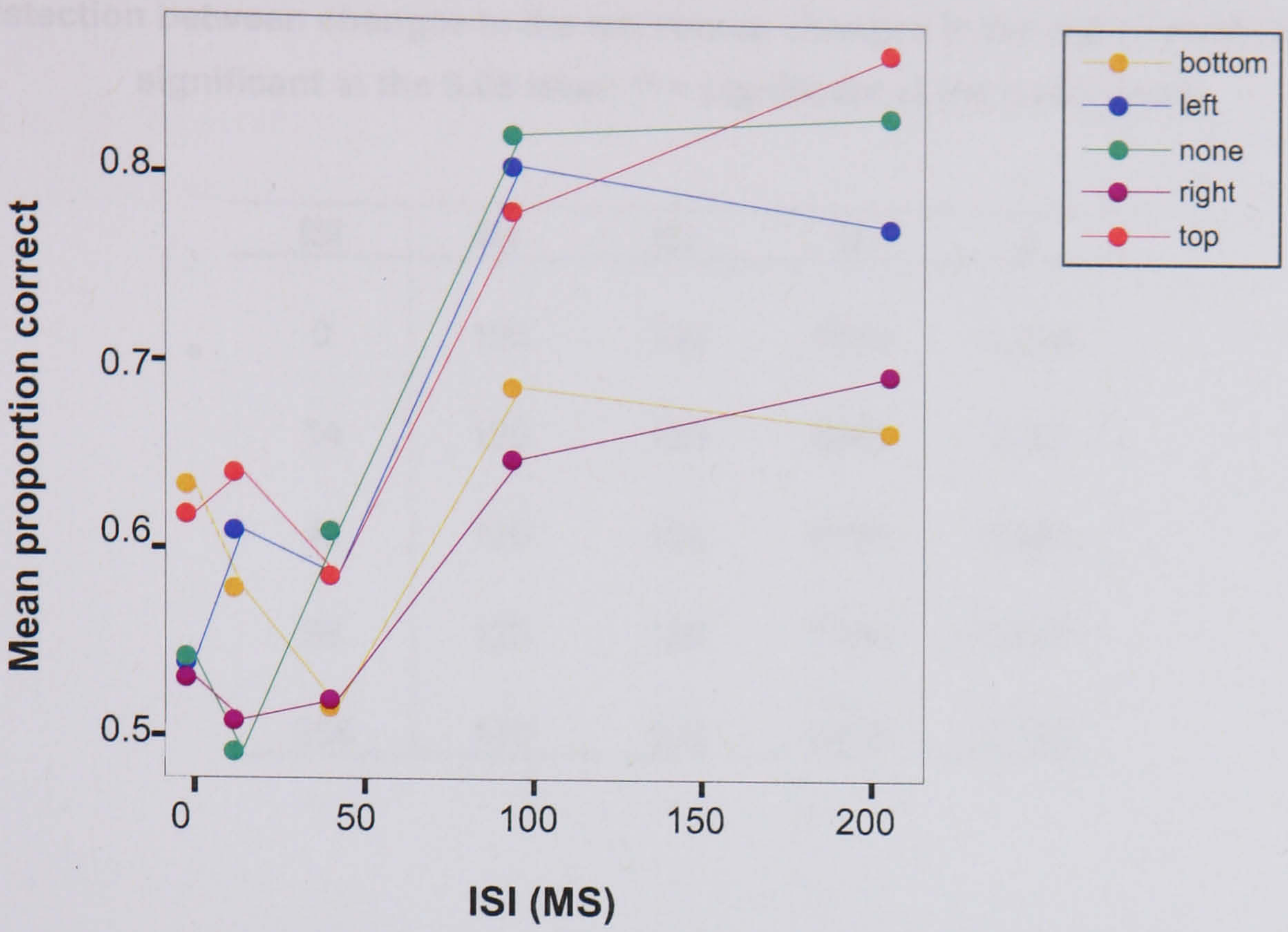


Figure 7.3: Mean accuracy in detecting differences for all symmetries for each of the five main conditions, change to the bottom half, top half, left side, right side of the image or no change at all.

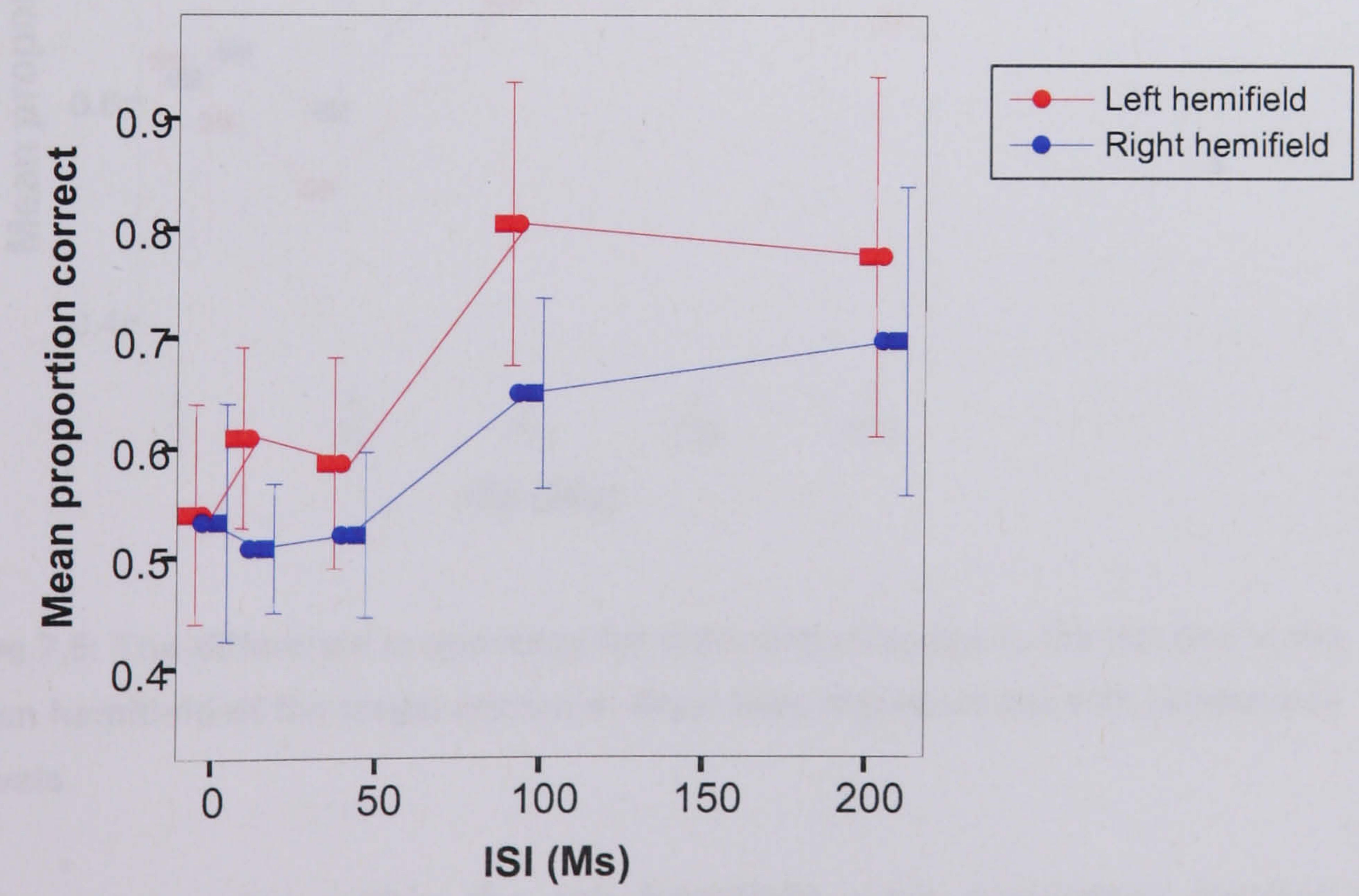


Figure 7.4: The difference in accuracy for detecting changes in the left and in the right hemifield of the target stimulus. Error bars represent the 95% confidence intervals.

Table 7.1: Mann Whitney U test for differences in the median values for accuracy of detection between changes in the left versus changes in the right hemifield (*= significant at the 0.05 level; ** = significant at the 0.005 level).

ISI	N1	N2	U	*p*
0	120	120	7080	0.796
14	120	120	6480	0.12
42	120	120	6780	0.363
96	120	120	6060	0.005**
208	120	120	6600	0.132

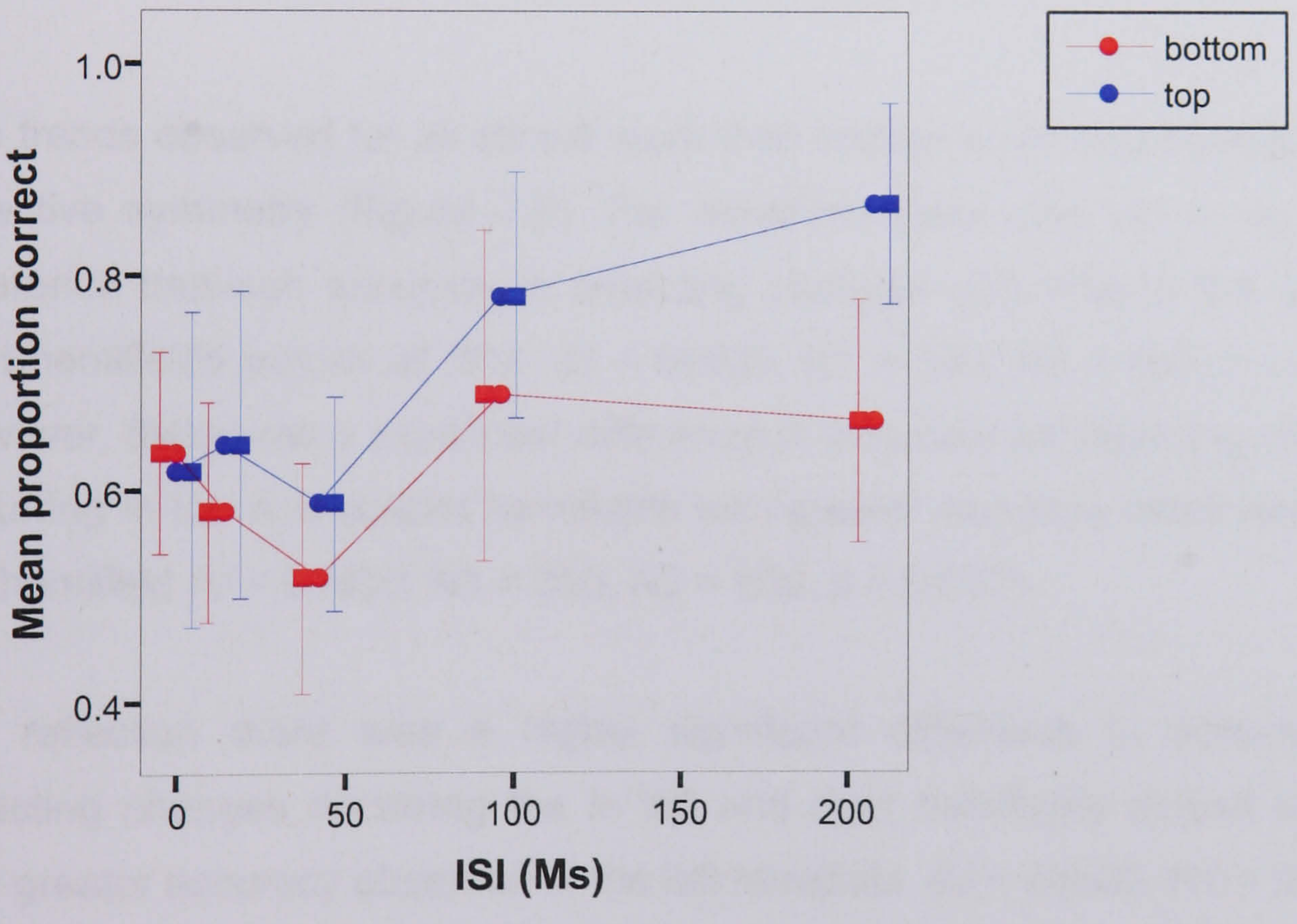


Figure 7.5: The difference in accuracy for detecting changes in the top and in the bottom hemifield of the target stimulus. Error bars represent the 95% confidence intervals.

Changes occurring within the top hemifield were accurately spotted more frequently than changes that occurred to the bottom hemifield. There was a significant difference in the accuracy (% score) between the identification of changes to the top hemifield when compared with changes to the bottom hemifield but only at ISIs greater than 96ms inclusive (Table 7.2, Figure 7.5).

Table 7.2: Mann Whitney U test for differences in the median values for accuracy of detection between changes in the top versus changes in the bottom hemifield (*= significant at the 0.05 level; ** = significant at the 0.005 level).

ISI	N1	N2	U	*p*
0	120	120	6960	0.595
14	120	120	6780	0.357
42	120	120	6660	0.243
96	120	120	6360	0.041*
208	120	120	5820	<0.001**

The trends observed for all stimuli were then broken down into repetition and reflective symmetry (Figure 7.6). For repetition there was not a significant difference between accuracy in detecting changes occurring in the left and right hemifields across all ISIs (U = 84600, N1 = 300, N2 = 600 p = 0.083). However, there was a significant difference in accuracy for detecting changes occurring in top and bottom hemifields with greater accuracy observed in the top hemifield (U = 81900, N1 = 300, N2 = 600, p = 0.007).

For reflection there was a highly significant difference in accuracy for detecting changes occurring the in left and right hemifields across all ISIs, with greater accuracy observed in the left hemifield (U = 80400, N1 = 300, N2 = 600 p = 0.002: see Figure 7.6). There was also a significant difference in accuracy for detecting changes occurring in top and bottom hemifields (U = 83400, N1 = 300, N2 = 600 p = 0.027: see Figure 7.6), again with greater accuracy in perceiving changes in the top hemifield.

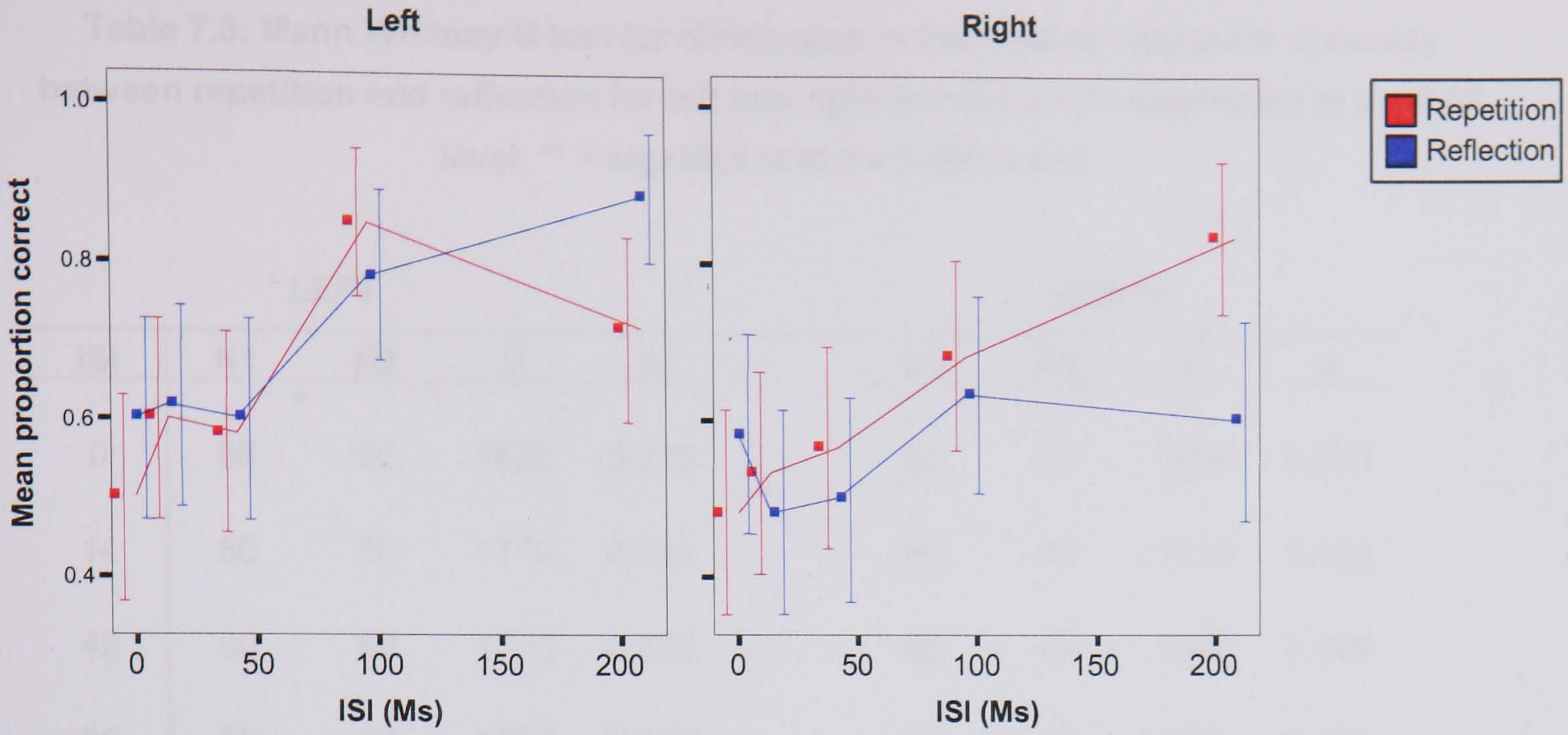


Figure 7.6: The difference in accuracy for detecting changes in the left and right hemifields of the target stimulus for repetition and reflection. Error bars represent the 95% confidence intervals.

In the left visual field neither of the pattern types has a general advantage over each other although there was a significant difference between reflection and repetition at ISIs of 208ms with reflection being more accurately perceived (Table 7.3, Figure 7.6). For the right visual field there is a trend in favour of repetition (Figure 7.6). This could reflect "simplicity" theories of pattern perception (Chater, 1996) in that the less information is required to reconstruct the rest of the repeated patterns as opposed to the reflective symmetry patterns in the visual field that is not primarily being attended to. Again this difference between repetition and reflection is significant at the 208ms ISI (Table 7.3).

Table 7.3: Mann Whitney U test for differences in the median values for accuracy between repetition and reflection for left and right hemifields (*= significant at the 0.05 level; ** = significant at the 0.005 level).

	LEFT				RIGHT			
ISI	N1	N2	U	*p*	N1	N2	U	*p*
0	60	60	1620	0.273	60	60	1620	0.274
14	60	60	1770	0.852	60	60	1710	0.585
42	60	60	1770	0.853	60	60	1680	0.466
96	60	60	1680	0.347	60	60	1710	0.565
208	60	60	1500	0.023*	60	60	1380	0.005**

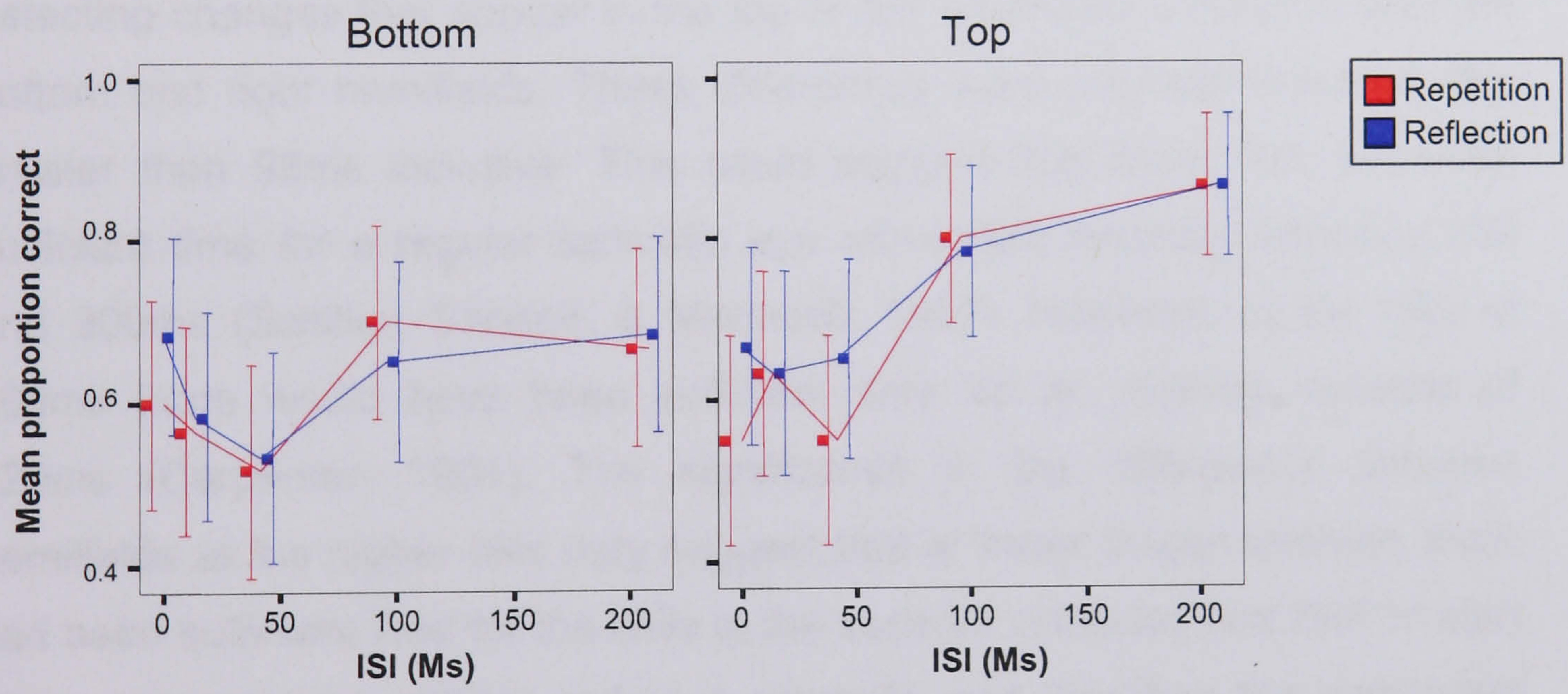


Figure 7.7: The difference in accuracy for detecting changes in the top and bottom hemifields of the target stimulus for repetition and reflection. Error bars represent the 95% confidence intervals.

There is no difference between repetition and symmetry between the top and bottom hemifields (Table 7.4). Both types of symmetry follow similar trends across each of the ISIs for each of the hemifields (Figure 7.7).

Table 7.4: Mann Whitney U test for differences in the median values for accuracy between repetition and reflection for bottom and top hemifields.

	BOTTOM				TOP			
ISI	N1	N2	U	*p*	N1	N2	U	*p*
0	60	300	8790	0.734	60	300	8340	0.288
14	60	300	8940	0.924	60	300	8340	0.295
42	60	300	8400	0.341	60	300	8700	0.634
96	60	300	8520	0.388	60	300	8580	0.44
208	60	300	8040	0.08	60	300	8160	0.106

7.9.3 Discussion of experiment 1

The results suggest that for the abstract patterns there was an advantage in detecting changes that appear in the top or left hemifields compared with the bottom and right hemifields. These differences were only significant at ISIs greater than 96ms inclusive. This could suggest that there had not been sufficient time for a regular saccadic eye movement requiring between 200 and 300ms (Schiller, Sandell, & Maunsell, 1987). However, at the ISIs of 208ms there would have been sufficient time for an express saccade of 120ms (Carpenter, 1981). The significance in the differences between hemifields at the higher ISIs may suggest that at these longer intervals there had been sufficient time for the cells in the superior colliculus and FEF to start firing, approximately 100ms before a saccade, and therefore the participant would have been particularly aware of the image. This suggests that the top left of an image is the area that predominantly captures attention first.

Comparing between pattern types there appears to be an advantage for repetition in the right hemifield, although only significant at ISIs of 208ms. This could suggest that there is a left hemisphere influence for serial processing of the repetitive stimuli, however this would be constrained by the effects of the general top-left bias across all pattern types There is a general right hemisphere advantage in that the left hemifield of the target is significantly more salient than the right hemifield of the target. These results suggest that reflective symmetry is being processed globally and that the repetitive patterns are being processed serially. This implies that the differences observed between reflective symmetry and repetition in previous backward masking experiments are probably due to a difference in processing strategies.

7.10 Experiment 2: Face experiment part 1 - Left / right hemifield biases in face perception

Following on from the abstract checkerboard stimuli, an ecologically valid face stimulus was used to investigate any hemifield biases within early perceptual processes. As a top-bottom bias in change detection had already been noted in chapter 6 for face perception, this experiment using the same basic faces, focused on the left-right hemifield effects. The aim was to see if there was a general bias in detecting changes in the left or right hemifield. This was achieved by either removing the left or right eye on the target face. A second part to the experiment utilised the detection of eye gaze direction as a more natural manipulation of hemifield biases in face perception. The aim of the second experiment was to see if directional information coded within the eyes had an affect on any hemifield perceptual biases.

7.10.1 Methods

7.10.1.1 Participants

Thirty-seven participants, 14 male 23 female were obtained from an opportunistic sample at the University of Gloucestershire. One participant was left-handed and the rest were right handed. All participants were offered £5 compensation for their time regardless of the number of trials they completed. All participants were aged between 19 and 40 years old all and had normal or corrected-to-normal vision. All participants provided their written informed consent prior to taking part in the experiment and were free to leave the experiment at any time.

7.10.1.2 Apparatus

The experimental apparatus was the same as in experiment.

7.10.1.3 Stimuli

The stimuli used were based on the same photo fit face stimuli used in the previous face masking experiments (see Appendix A). The eyes had previously been identified as a particularly salient feature of the faces during masking experiments so the changes in this experiment involved the removal of an eye from either the right or the left facial hemifield (Figure 7.8).

Original Left eye Right eye

Figure 7.8: Examples of the stimuli for the face condition. The 3 basic conditions are unaltered original picture, a picture with the left eye removed and a picture with the right eye removed.

In the practice trials randomly generated photo fit faces were used over a longer duration ISI (500 ms). The stimuli were presented in the middle of the display at a size of 21cm x 21cm and an approximate visual angle of 18°. The presentation of the fixation point was central to the faces presented, i.e. neither hemifield was at an advantage due to the fixation process. The visual angle of the eyes was approximately 3.08° from the central point of fixation point.

7.10.1.4 *Procedure*

The participants were seated in the experimental area. The researcher remained with the participants while they worked through the instructions but left as soon as the practise trials started so as not to distract the participant.

The masking procedure described in the general methodology chapter was used. The ISIs used were the same as those used in the previous face masking experiment, these were 0, 14, 28, 56, 154 ms. The experiment took approximately 10 to 15 minutes and consisted of 50 main trials. The order of presentation was randomised to minimise priming or cueing effects.

The participant was told to identify whether the image presented at the end of the each trial was the same as the one presented at the beginning of each trial. In the practise trials the stimuli consisted of randomly generated photo fit stimuli with an ISI of 500 ms. Once the participant had reached 80% accuracy on the practise trials they were able to continue to the main trials, the practise run consisted of 10 trials per cycle, all participants obtained 80% after one cycle of practise trials. Once the trials were completed, the participant was offered a chance to provide feedback on the experiment and was fully debriefed. Non-parametric tests were used to analyse the data as the data are not normally distributed and do not exhibit homogeneity of variance.

7.10.2 Results

A Kruskal-Wallis test was conducted to compare the differences between the proportions of correct responses in the detection of changes occuring to either hemifield. The loss of an eye to the left side of the image was significantly more apparent than the loss of an eye to the right side of the face (Figure 7.9, Table 7.5). By 154ms all conditions exhibit a similar degree of accuracy. The results appear most significant when there was no ISI, with no significant difference in accuracy at the 14ms ISI.

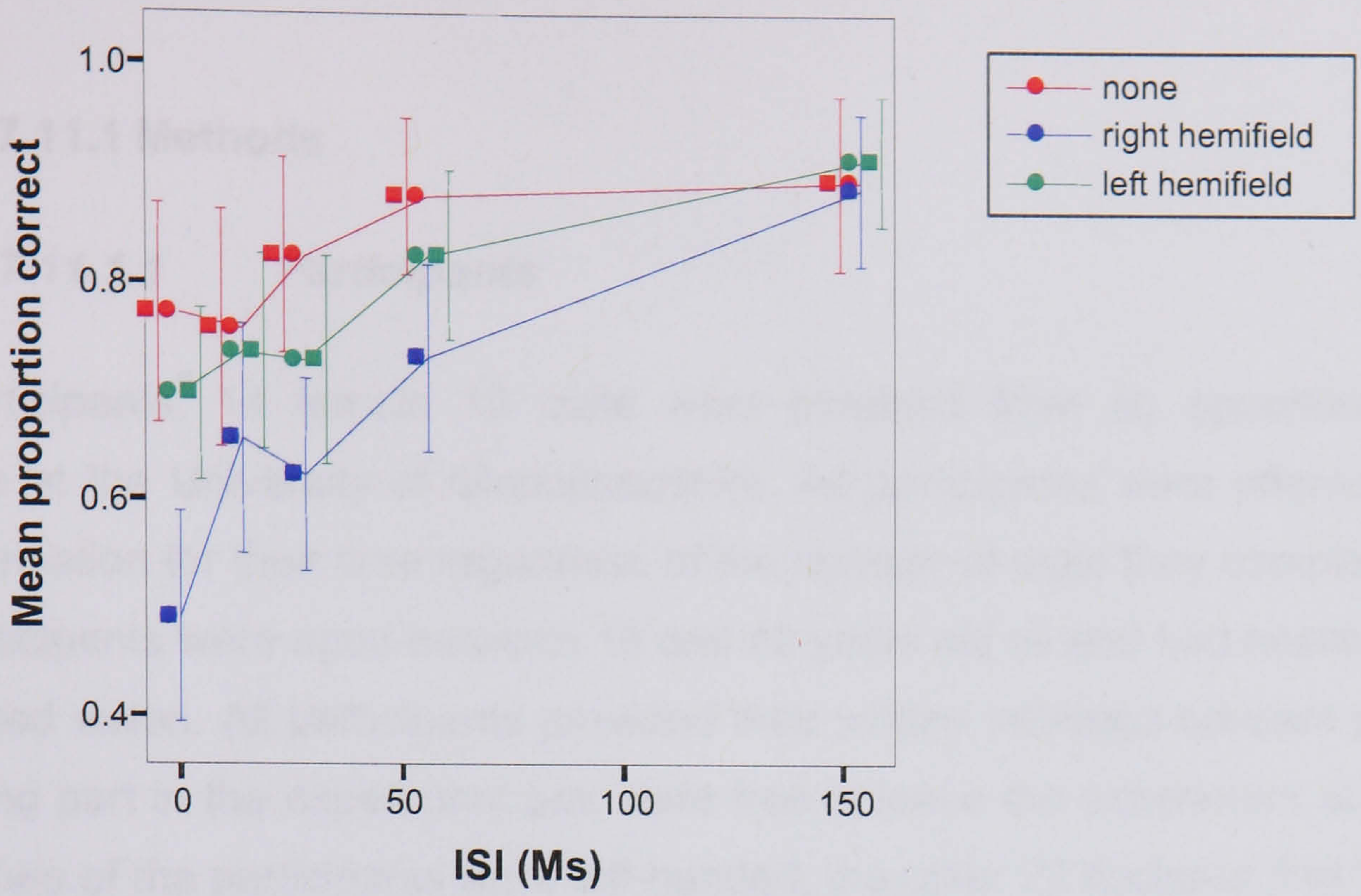


Figure 7.9: Accuracy of detection (proportion correct) in the detection of eyes missing from either the left side of the image, right side of the image or no change at all (none).

Table 7.5: Kruskal-Wallis test for differences between responses for loss of eye in the left side, right side, or no loss of eye in the target face (*= significant at the 0.05 level; ** = significant at the 0.005 level).

ISI	df	χ^2	*p*
0	2	21.56	<0.001***
14	2	3.36	0.187
28	2	10.39	0.006**
56	2	7.839	0.02*
154	2	0.538	0.764

7.11 Experiment 2: Face experiment part 2 - Effect of gaze direction and hemifield bias

7.11.1 Methods

7.11.1.1 Participants

24 participants, 14 female 10 male were obtained from an opportunistic sample at the University of Gloucestershire. All participants were offered £5 compensation for their time regardless of the number of trials they completed. All participants were aged between 19 and 40 years old all and had healthy or corrected vision. All participants provided their written informed consent prior to taking part in the experiment and were free to leave the experiment at any time. Two of the participants were left-handed; the other 22 declared that they were right-handed.

7.11.1.2 Apparatus

The experimental apparatus was the same as in experiment 1 (Chapter &; page 201).

7.11.1.3 Stimuli

The stimuli used were photographs that were manipulated using Paintshop Pro 8. The changes to the stimuli involved variations in gaze direction. Gaze direction was chosen to represent more natural stimuli than the one-eyed photo fits used in the previous experiment. There were seven different face types and for each face type 3 different contrasts, natural, 50% contrast reduction and 70% contrast reduction. The change in contrast was to vary the pop-out effect of the eyes in order to get a clear idea of which side was being attended to first. The 7 face types are illustrated in Figure 7.10. The stimuli were presented in the middle of the display at a size 21cm x 21cm and an approximate visual angle of 18°. The visual angle of the eyes was approximately 2.64° from the central point of fixation. All stimuli were presented in greyscale.

Figure 7.10: The seven different face-type conditions: a) looking straight ahead, b) right eye looking left, c) right eye looking right, d) left eye looking left, e) left eye looking right, f) both eyes looking left, g) both eyes looking right (each was shown at 3 contrast levels).

7.11.1.4 *Procedure*

The participants were seated in the experiment area. The researcher remained with the participants while they worked through the instructions but left as soon as the practice trials started so as not to distract the participant.

Participants had to identify if either of the eyes were looking away from direct gaze and if so in which direction. Participants were shown examples of the pictures prior to the experiment so they could familiarise themselves with the keys and conditions. There was a trial run with no masking so that the participants could practise. The masking procedure described in the general methodology chapter was used. The ISIs used were the same as those used in the previous face masking experiment (pg), these were 0, 14, 28, 56, 154 ms. This experiment varied from part 1 (section 7.9) in that rather than detecting whether an image is the same or different the participants responded with which direction they thought the face was trying to look, either left, right or straight ahead. This was done using the ‘1’, ‘2’ and ‘3’, keys on the keyboard. Although this could incur extra cognitive processing on the part of the participant, all participants were familiarised with the type of stimuli and the response keys before starting the experiment. The experiment took approximately 20 to 25 minutes and consisted of 135 main trials. The order of presentation was randomised and balanced between conditions to minimise priming or cueing effects. The testing procedure was the same as in experiment 2.1.

7.11.2 Results

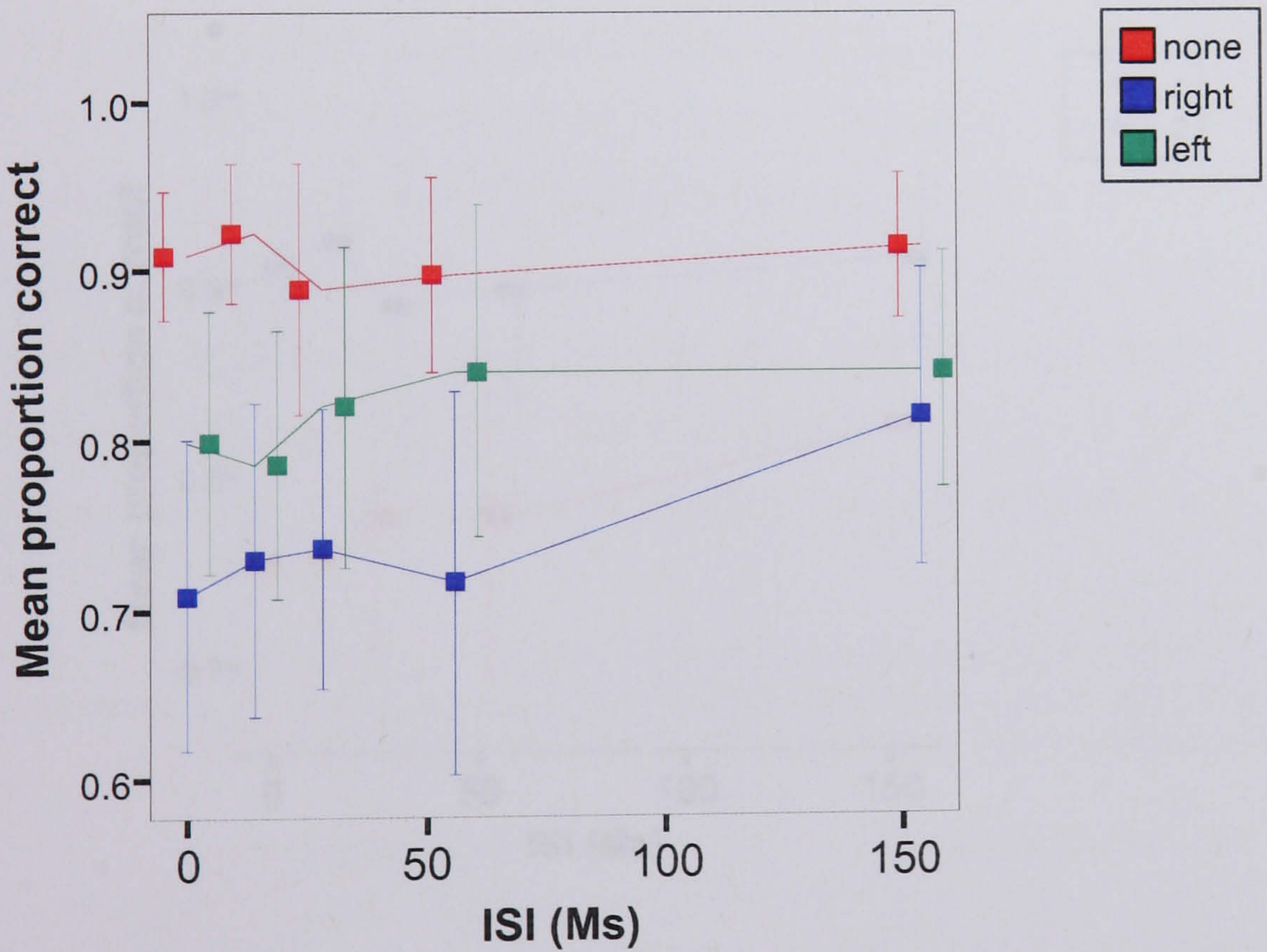


Figure 12: Visual field bias (based on side on which side of face had a deviation in eye direction from looking straight ahead). Error bars represent the 95% confidence intervals.

Again there is a highly significant bias towards the left eye relative to the right eye at all ISIs except at 156ms (Table 7.6). When both eyes are looking straight ahead there appears to be little problem in detection regardless of the ISI (Figure 7.11). All the conditions appear salient with the mean proportion correct consistently above 70% across all the ISIs.

Table 7.6: Kruskal-Wallis test for differences between responses for side of face that deviation in eye gaze from looking straight ahead (*= significant at the 0.05 level; ** = significant at the 0.005 level).

ISI	df	χ^2	p
0	2	10	0.007 **
14	2	9.07	0.011*
28	2	9.99	0.007**
56	2	7.66	0.022*
154	2	2.29	0.319

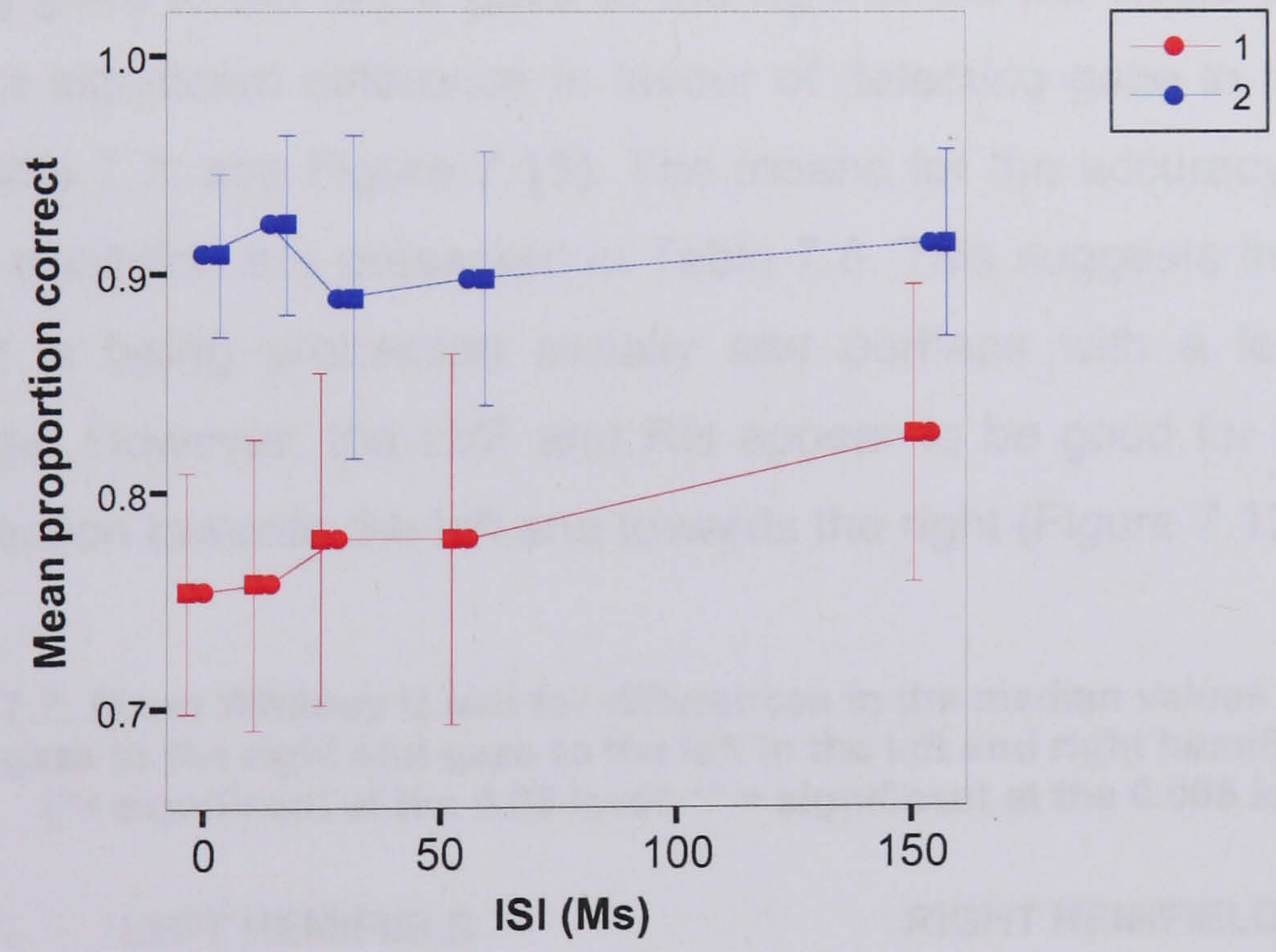


Figure 7.12: Influence of the number of eyes involved in indicating gaze direction on accuracy. Error bars represent the 95% confidence intervals.

The number of eyes that are involved in the direction of gaze have a highly significant effect on the results indicating two eyes are better than one at signalling orientation (U = 3370, N1 =120, N2 –120, p< 0.001; see Figure 7.12).

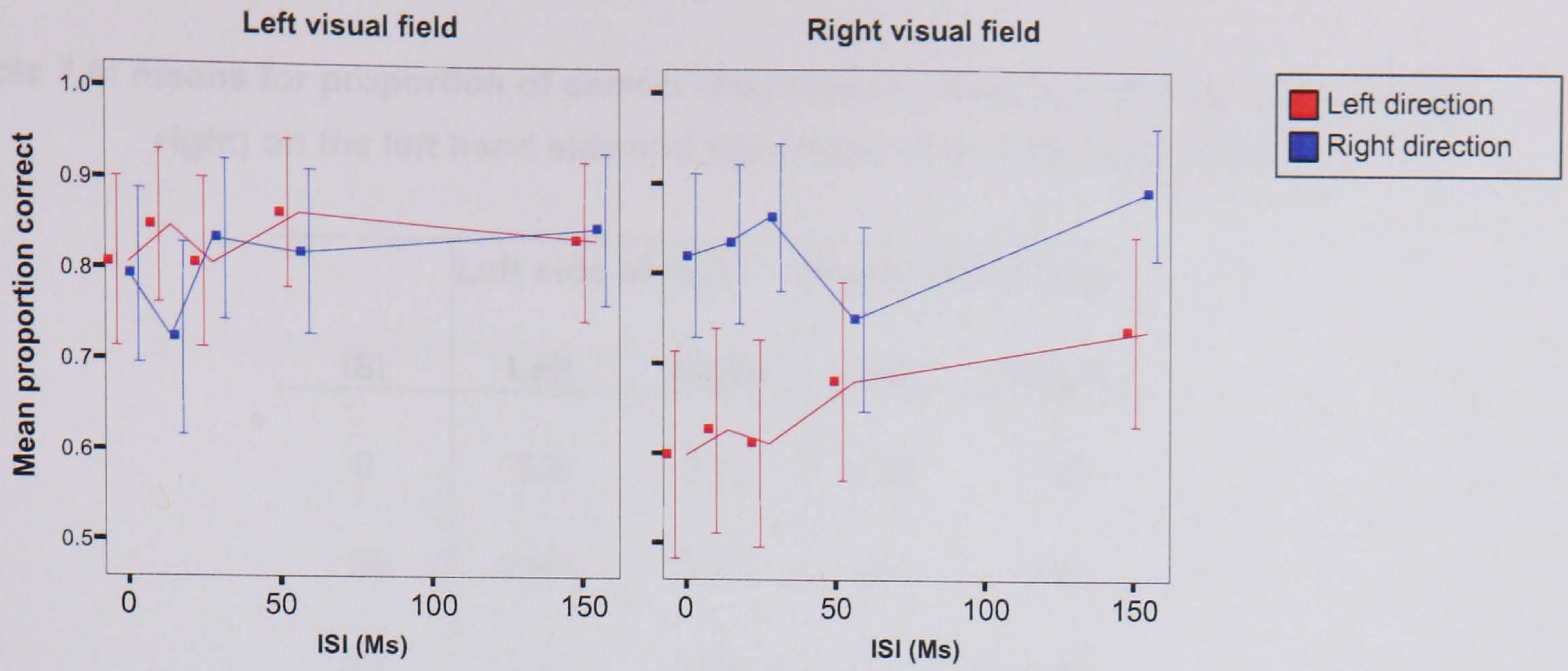


Figure 7.13: The bias towards different gaze direction as a function of visual field in which deviation from looking straight ahead occurs. Error bars represent the 95% confidence intervals.

Figure 7.13 shows that gaze direction towards the right is more frequently detected in the right visual field. There is no significant difference between detecting gaze to the left & gaze to the right in the left visual field. However, there is a significant difference in favour of detecting gaze to the right in the RVF (Table 7.7: see Figure 7.13). The means for the accuracy of responses for each condition are presented in Table 7.8. This suggests that the gaze to the right is being processed serially and perhaps with a left hemisphere advantage. However, the LVF and RH appear to be good for both detecting gaze direction towards the left and towards the right (Figure 7.13).

Table 7.7: Mann Whitney U test for differences in the median values for accuracy between gaze to the right and gaze to the left in the left and right hemifields of the face (*= significant at the 0.05 level; ** = significant at the 0.005 level).

	LEFT HEMIFIELD				RIGHT HEMIFIELD			
ISI	N1	N2	U	p	N1	N2	U	p
0	72	72	2556	0.836	72	72	2016	0.003**
14	72	72	2268	0.069	72	72	2052	0.005**
28	72	72	2520	0.666	72	72	1944	0.001**
56	72	72	2484	0.496	72	72	2412	0.358
154	72	72	2556	0.821	72	72	2196	0.019*

Table 7.8: means for proportion of correct responses in detecting gaze direction (left or right) on the left hand side and right hand side of the target face

	Left side of face		Right side of face	
ISI	Left	Right	Left	Right
0	0.8	0.79	0.59	0.82
14	0.85	0.72	0.63	0.83
28	0.81	0.833	0.61	0.86
56	0.86	0.82	0.68	0.75
154	0.833	0.85	0.74	0.89

7.12 Experiment 2 discussion

7.12.1 Bias towards left side of face

In the first part of the experiment there was a bias towards correctly identifying changes occuring in the left side of the face this reflects the left hemifield bias identified in the abstract experiment (section 7.9). In the second part of the face experiment there was a bias towards correctly detecting eye gaze presented in the left side, i.e. LVF, of the face. This could suggest a RH dominance in the processing of facial stimuli. The left hemifield bias in correctly detecting eye gaze may indicate that at early ISIs the RH dominates the orienting of visual search. At ISIs less than 154ms there is insufficient time for a complete normal saccade of the eyes. Normal saccades of the eyes take approximately between 200 and 300ms (Schiller, Sandell & Maunsell, 1987). This may reflect the time it takes to consciously shift attention to a new locality within the target image, hence the shorter ISIs would inhibit the reorientation of attention.

The bias towards detecting change and gaze direction in the left hemifield may support the evidence provided by Sackeim (1978) that the presence of a stronger facial signal in the RVF would aid communication of rapid and subtle emotional signals that would be possibly missed by the dominance the LVF. The evidence from these two experiments into left/ right hemifield differences in face perception suggest that at brief ISIs attention is focused on the face in a similar way to the abstract patterns of experiment 1 (section 7.9)

7.12.2 Bias toward gaze direction

There was a significant difference in the accuracy of detection of gaze direction based on one eye or two eyes signalling the direction. This suggests that the synchronisation of eye behaviour is important in the signalling process and that the eyes are perceived as a single unit. The presence of two eyes will amplify any signal and ensure that gaze direction is accurately interpreted. However this single perceptual unit is still subject to bias towards perception of the left side.

Again participants showed a bias towards correctly identifying changes to the left hemifield. However there was also a bias towards eyes looking to the right in the right half of the face. This may have been because when the eyes are looking to the left, they are acting as a cue orientating visual search away from the face (Caron, Butler & Brookes, 2002; Tipples, 2002). When the eye within the LVF is staring straight ahead or to the right, then there will be a bias towards scanning the rest of the image as eye gaze is either contained within the face or directed across it. This may suggest that the eyes might be directing the orientation of visual search, i.e. if the eyes look to the left there is bias on the participants to remain focused on the left side of the face. However if the eyes are looking to the right then there is a tendency to look across the face.

The second face experiment also examined changes in the eye contrast and the results mirrored those of the previous contrast study in that a reduction of 70% in the contrast between the sclera and the iris resulted in a reduction in correct detection. In the detection of gaze direction accuracy was increased if both eyes were looking in the same direction. This would be particularly important when having to look across the face to follow eye gaze to the right, therefore the eyes not only provide redundant information but can also provide supplementary information to promote gaze detection.

7.13 Discussion of hemifield biases

Two different types of stimuli were investigated in detail. These were checkerboard patterns and faces. The checkerboard patterns were presented in the same conditions as in the symmetry masking experiment (Chapter 5), masked at ISIs of 0ms, 14ms, 42ms, 96ms and 208ms. The face stimuli were masked at ISIs of 0ms, 14ms, 28ms, 56ms, and 154ms and presented in two experiments one using the stimuli from the face masking experiment (Chapter 6) and the second using photographic stimuli.

The results of the checkerboard hemifield experiment showed that there was a bias towards detection of changes in the left side and top half of the target stimulus. Repetition had an advantage over reflection in the right hemifield suggesting that the redundant information contained within repeated stimuli aids identification of stimuli when the whole image is not fully attended to. However there was no differential bias for either of the symmetry types in the LVF. The RVF bias towards repetition could reflect the simplicity theory of symmetry detection (Chater, 1996) in that the information would be easier to extrapolate and predict across a greater spatial area than the reflected stimuli. This bias towards repetition might prove to be stronger in the RVF due to sequential processing abilities or the local processing abilities of the LH (Robertson & Lamb, 1991; Delis et al., 1986).

However in the top/bottom variations there was no bias towards one symmetry type in the identification of changes. This could suggest that the extrapolation of patterns may be preferentially carried out across the horizontal plane. However, Julesz (1971) suggests that such a top to bottom processing bias in visual perception could be a result of the positioning of the visual sensory equipment. As the eyes are located towards the top end of the body then scanning will be preferential in line with the horizon and then from the horizon downwards during visual search. However, a bias towards scanning the periphery of objects, i.e. the top left of an image, does reflect the findings of studies into early neonate visual perception of faces (Maurer & Salaptek, 1976). The early ISIs of the masking methodology might be reducing the acuity of the target images and resulting in a greater reliance on subcortical visual processes.

The results of the first face hemifield experiment showed that there was a bias towards detecting changes to the eyes in the left hemifield. However, faces provide a special case in that emotional expression appears to be stronger in the left side of an individual's face (Sackeim, 1978; Nichols et al., 1999), which is presented to an observer in the right hemifield. As the experiments in this thesis suggest a LVF bias in early perception would mean that the presence of a stronger facial signal in the RVF would aid communication of rapid and subtle emotional nuances. A second experiment was conducted factoring in gaze detection, whereby the participant had to identify which direction a face was looking. The same LVF field bias in early perception was observed however the redundant information provided by the repetition of the eyes maximise the signal and accuracy of participants judgements regarding gaze direction.

This investigation into hemispheric biases in early visual perception, suggest that the patterned nature of an object may be a significant factor in making rapid judgments during brief presentations. For example in the abstract masking condition the repetitive patterns had a RVF advantage over reflected patterns that might suggest that the rest of the scene is filled in by the brain using the minimum amount of information.

However sufficient information is provided from backward masking experiments to make judgements regarding the presence of a stimulus. This is illustrated by the high accuracy rates for certain types of stimuli (E.g. eyes) that are highly salient. The high contrast nature of the eyes means that by even using low acuity visual pathways such as that of the superior colliculus sufficient information is provided to orientate attention (Johnson & Morton 1991).

The bias towards the LVF for eyes and symmetry suggest that there is global processing of facial stimuli while the RVF bias for repetition could indicate a serial processing strategy. This has implications for how an individual would perceive a social situation. When in social groups, such as conversation groups, an individual has to attend to the requirements of more than one individual. The sub-cortical pathways provide a method for rapidly switching attention in response to eye movements, however the visual field biases might conflict with this in constraining the focus of attention onto the left side of the group. However if the group were processed serially as in repetition then there would be RVF bias. The salience of the eyes might also act as a constraint drawing attention to only one point of the social group at any one time. The influence of visual field biases and the focus of attention on group size are investigated further in the following chapter.

Chapter 8: The application of pattern perception to the perception of social groups

8.1 Visual perception of human social groups

The early visual perception of faces and abstract patterns has been explored in terms of hemifield biases, orientation and saliency of symmetry type. In the natural world, however, it is rare to see a single stimulus presented in isolation and out of its natural surroundings. It has been shown that the context within which an object or face is initially presented has a significant impact on performance in recognition tasks. If the initial context is not replicated the recall of the stimulus is impaired (Bruce & Valentine, 1986; Ellis & Young, 1998; Memon & Bruce, 1983; Palmer, 1975; Young, 1998). One of the common ways that faces are encountered is within the context of free forming social groups, for example conversational groups. It is within such groups that faces are of particular importance as signalling devices.

Continuing on from the pattern perception experiments previously described (Chapters 5 to 7) the following chapter investigates the implications of the previous findings on the perception of small social groups. The eyes and face have been identified as salient stimuli within an individual face. The implications of repeating the stimuli, as would be experienced within conversational groups, could alter the clarity of perception of the group members remote from the point of fixation within the field of vision. As previously examined, repetition and symmetry both provide an element of redundancy in information processing and allow for conclusions as to the nature of object properties. Reflective symmetry is strongly associated with object and global perception and repetition is associated with background perception or serial processing. However conversation groups can be perceived in either manner, as a unified whole or as a series of repeated elements. In addition to the literature reviewed on symmetry and face perception further variables have to be accounted for before examining the issue of social group perception. The following sections will review the relationships between the visual system and social group size, and relevant attentional literature.

8.2 Free forming social groups

It is first necessary to define and describe the characteristics of free forming social groups. One characteristic of free forming social groups is the proximity of individuals to each other due to auditory and visual constraints. On average observed free forming conversational groups consist of four people (Dunbar, Duncan & Nettle, 1995). If the group size increases above this number, the group will fission into new subsets of sizes of four or less. Dunbar et al. (1995) suggested that one of the constraints placed upon the conversational group size is that of audibility. With noise levels in a large office typically being around 50db a maximum group size of approximately three or four individuals would be predicted. If more than 4 people are involved the consequent social circle formed by the group would result in reduced detection of the conversational topics. However, considering human social interaction is accompanied by a large variety of visual cues, be that eye gaze or facial expressions, this could place an additional constraint on the detection of other group members. It is therefore possible that limitations based upon the visual system and attentional processes could play a significant role in our detection of social agents.

There are several factors emerging from previous studies into face and pattern perception that could influence the predicted group size in social situations. The first factor is that of the field of vision, as with the studies into reflective symmetry there appears to be greater salience of perceptual elements that are close to the central vertical axis of a scene, similarly the proximity of group members to a point of fixation could have implications for free forming social groups. The field of vision also contains blind spots and is limited to a 180° viewpoint without the use of head movements. The second factor is that of the complexity of the social signals that are used during conversations. These complex signals involve not only vocal communication but also the use of facial expressions and movements that indicate the inner-thoughts of the signaller (Baron-Cohen, 1997; Jellema et al., 2000). A third factor to consider is that of a processing limitation within the visual cortices. In several studies of primate societies, cortical limitations have been linked with groups size (Barton, 1996; Dunbar, 1992, 1993; Kudo & Dunbar, 2000)

These factors can be illustrated by examining data collected from classical English drama. In a study of 10 Shakespearean plays it has been suggested that the number of characters that are present within each scene reflect similar numbers to those observed in human support cliques and conversational group sizes (Stiller, Nettle & Dunbar, 2003). The constraints for staging drama are similar to those of perceiving a conversational group; if there are too many characters interacting on a stage it is difficult to focus attention on a particular unit. By having fewer characters the field of vision is not being stretched and the number of head movements required is reduced. Secondly the characters are presented proximately and therefore perceived as a social gestalt and not as isolated units. This reinforces the idea that the characters are interacting. Rather than overwhelm a scene with characters Shakespeare would, as in real life social groupings, break the groupings up and create new scenes. Not only does this maintain the realism of the onstage social interaction but reduces the information load that has to be tracked by the audience be that by following visual gestures or verbal intentions (Stiller & Hudson, 2005).

So far the arguments suggests that the visual system could have a strong influence on the formation of observable social groups. If this were the case then it would suggest that primates with larger visual cortices would have more complex social groups.

8.3 The observed relationship between group size and the visual cortex

It has been shown that there is a positive linear relationship between social group size and neocortex size amongst primates (Dunbar, 1992). Therefore it could be argued that the capacity of the neocortex for handling social information constrains some of our social functions. This might be the case for large social networks where many different relationships have to be tracked and processed. However, the same neocortical constraints do not necessarily impinge on the processing of more immediate social interactions such as that of conversational groups where the number of relationships that need to be tracked are greatly reduced. These smaller conversational groups do not necessarily have to be composed of close friends so the need to track personal information that would be characteristic of emotional support networks is not replicated (Kudo & Dunbar, 2000). The constraints on free forming social groups are probably the result of the information input devices, the eyes and the ears, rather than cortical processing limitations such as memory and recognition. This would therefore indicate a bandwidth problem as opposed to a processing constraint. The visual cortices in particular represent an input system that is limited by the direction an individual is looking and sensitivity to light levels. In order to elaborate on this it is necessary to consider how the visual cortex has evolved in relation to other brain areas.

Barton (1996) suggested that amongst diurnal primates the visual system might be implicated with the social complexity of the primate groups with variance in the size of the primary visual areas being associated with the parvocellular, as opposed to magnocellular pathways. The ability of the parvocellular pathway to perceive fine detail and colour perception could be advantageous when managing the many socially complex signals that are produced within primate societies such as subtle face movements or gestures. This would suggest that cortical visual processing systems provide a partial limitation on the development of primate social groups.

Stevens (2001) demonstrated that the number of neurons in the LGN scale allometrically with the number of neurons in area V1 with a 3/2 power relationship. This scaling property was found to be true not only across primate species but also within species, e.g. humans. Stevens suggests that this relationship was due to a need for accurate mapping of orientation within the 3-dimensional space of the primary visual area. Therefore in order to maximise the resolution of the image there has to be an increase in the number of neurons within the area V1 as compared to the LGN or retinal ganglion cells. This would allow for the detection of very fine facial expressions and subtle movements that would make the primate visual system expertly tuned for detecting social agents and as suggested by Barton (1996) this would prove essential for successful interaction within free forming social groups. However there is also an allometric relationship between the size of the LGN and the neocortex (non-striate cortex), so perhaps correlations between the volume of the neocortex and group size could be the product of visual processing limitations.

It has been shown that there is a weaker correlation between primate social group size and the striate cortex as compared with the extra-striate cortex; this suggests that the relationship between neocortex size and group size is of social skills, such as Machiavellian intelligence and not visual recognition (Byrne & Whiten, 1988; Joffe & Dunbar, 1997). In evolutionary terms this would suggest that the social processing of information is strongly associated with group size as opposed to ocular ability. However in certain situations the capacity of the visual system will affect higher analytical brain functions, for example the range of visual signals used and detected will reflect the capacity of the visual system. However the ability to use top-down processes to direct attention and explore the environment mean that any limitation in capacity can be compensated for, as the visual experience is not merely passive viewing.

When looked at from a comparative perspective, there is a linear relationship between the increase in striate and non-striate cortex amongst most animal species, i.e. as the number of visual areas within the brain increase then so do the number non-visual areas (Stevens, 2001). This could suggest that the increase in the striate cortex is determining the overall size of the neocortex. However amongst the apes there appears to be a great acceleration in the growth of the non-striate cortex compared with that of the striate cortex resulting in an evolutionary plateau in the relationship (Joffe & Dunbar, 1997). This could suggest that due to the constraints of the hardware, i.e. eyes and optic nerves, there is a limit to the amount of development within the striate cortex. In the next section the limitations of the visual hardware are discussed in relation to social groupings.

8.4 Foveal vision and group size

The human eye, as with all diurnal primates, consists of one foveal area (Fleagle, 1998). Visual acuity decreases with increasing eccentricity from the fovea and by 10°, visual acuity is reduced to only 25% of that of the fovea. Within this area of the retina is the highest concentration of cone cells, whereas at around 10 to 15 degrees of the fovea is the highest concentration of rod cells (see Chapter 2). This foveal area is particularly important in obtaining the fine detail information that is necessary for the binding of features and the focusing of attention. It is therefore possible that the human visual system is both limited by the input it receives from the outside world and the area attended by foveal vision. Previously it has been argued that the human visual system has a particular sensitivity to human social signals i.e. facial signals. The high acuity areas would enable the discrimination of complex and subtle facial signals and expressions that commonly occur among many diurnal primate species (Zeller, 1987; Barton, 1996). Evidence from Primate studies show that other primate species, for example rhesus macaques, *Macaca mulatta* (Hinde & Rowell, 1962) and chimpanzees, *Pan troglodytes* (Menzel, 1971, 1975), utilise visual signals in communicating subtle social and environmental information to conspecifics. This information is used to ascertain the emotional states, cooperative intentions and to reassure other group members. This evidence suggests that the use of direct visual signals is essential in the cohesion of primate social group sizes. However the detection of such signals will be constrained by the visual hardware used. Problems such as blind spots and the retinal field of high acuity vision will all impact on visual perceptions of social groups.

The life strategies of a species appear to be crucial in the adaptation of the eye. In socially foraging birds, group size is a critical factor in the transfer of information regarding food or vigilance. It is suggested that the visual acuity of these birds might be correlated with the critical density and spacing of social foraging birds (Fernandez-Juricic et al., 2004). The type of avian visual system might prove essential within different groups. The raptors for example are predatory animals that live in small groups and possess a small cyclopean and lateral field. The raptor visual system would not be suitable for large groups where competition and opportunism would be a threat. However amongst smaller flocking birds the trend is reversed as there is often greater competition for resources and the continuous risk of predation. Many bird species have been identified as having two foveas enabling them to forage utilising the frontal field and stay alert to conspecifics and predators using the lateral field (Martin, 1994).

The reduced risk of predation amongst humans and the forward facing position of the eyes means that there is little need, as with many bird species, for two foveal areas. However the foveal area occupies a comparatively small area of the retina and this will affect the way conspecifics are processed within social groups. With only the frontal eye field covered there needs to be greater visual acuity in front of the observer, for both threat detection and alliance formation. Therefore there is a greater need for the expansion of the parvocellular pathways to analyse in detail the subtleties of the information presented and a suitable processing and association cortex to accommodate the additional information load. This might provide an explanation for the observed allometric scaling between the LGN and the V1 areas put forward by Stevens (2001).

The ability to focus or broaden attention in response to various visual stimuli is an important factor in ascertaining any relationship between vision and group perception and maintenance. Attention is of particular importance as demonstrated in the masking experiments, with certain stimulus types appearing to be more salient and capturing more attention. The next section examines some of the evidence from attentional studies.

8.5 The attentional window and feature binding

Posner (1980, 1994) noted that by brightening a frame prior to the presentation of a target in a second frame, would speed up the detection of a target object presented outside of the central fixation area. The brightening of the frame widened the participants' area of focus beyond that of the fixation stimulus. Posner argues that this results in a change in the size of the attentional window. In this argument the area that can be attended at any one moment can be enlarged or reduced dependent on the properties and size of the stimulus. This is in accord with the work on global and local processing in that there can be a switch from focusing on global and local letters when looking at nested letter stimuli (Navon, 1977). These switches in attention from local to global reflect a re-scaling of the attentional window and the fractal nature of visual perception.

Within the visual cortices, evidence suggests that the receptive field of area V4 is linked to the attention of objects (Moran & Desimone, 1985). Moran and Desimone demonstrated that there were changes in the size of the receptive field in relation to the size of the attentional window. So the receptive field in V4 shrinks to exclude those objects that are not being actively attended. Similarly damage to the parietal lobes has been identified as affecting the focusing of attention towards different areas of the visual field. This implies that attention is spatially selective and that objects that fall outside of this area cannot be accurately recalled or identified.

It has been suggested that spatially selective attention may play a role in feature binding (Treisman & Gelade, 1980). Objects are coded one at a time on the basis of location, by temporarily excluding the other surrounding stimuli. The window of attention is therefore small and the features can be bound without any interference from competing stimuli. However if there is competition from other visual elements illusory conjunctions can be formed (Intraub, 1985; Treisman & Schmidt, 1982). An illusory conjunction occurs when the features from neighbouring objects, for example colour or texture, become perceptually bound into a target object.

In a series of experiments that examined illusory conjunctions Treisman & Schmidt (1982) presented 4 shapes to participants that varied in size, colour and shape. Two digits flanked the 4 shapes and the participants were told that their primary objective was to identify these digits. However, the participants were subsequently asked to recall all the features of one of the shapes. Participants tended to make errors by binding the features of conjunctive objects together. Another variation was the use of colour and letters, the participants would then attribute the wrong colour to the wrong shape. This suggests that the features of the objects are bound in parallel and if not fully attended confusion within these streams can result in illusory conjunctions. However if the subjects were cued to look for a particular colour shape then they report the shape more accurately. This reflects a top-down template matching approach (Wolfe et al., 1989; 1995).

Although the sense of seeing is one of a unified percept, the visual scene is actually not attended as a whole, as different areas elicit different perceptual processes. Zeki (1993) suggests that there are several maps of the visual scene laid out in different areas of the brain. So for example a face would activate the face processing areas while other areas might be activated for motion, colour, and depth. This presents the problem of binding of the visual scene, in other words how does an individual know that an apple is green and round. The process can be either a top-down process, i.e. the individual actively seeks out the criteria from the optic array, or the process can be bottom-up in that the features are serially identified and matched before there is any identification. Gray et al (1989) and Singer and Gray (1995) demonstrated the presence of stimulus dependent synchrony between units in widely separated brain areas. They suggest that this synchrony between areas results in the binding of perceptual elements. However there are possibly limitations to the amount of cortical areas that can be tagged in order to allow for the binding of these perceptual elements.

Evidence from studies using Gabor patches has shown that by focusing attention on a target there is increased sensitivity to its contrast and spatial resolution (Carrasco et al., 2000; Carrasco et al., 2004). This would have implications on the perceptions of social group sizes in that even within the field of high acuity vision, objects might not be accommodated within the focus of attention if this attention is drawn towards areas held by high contrast features. The elements that capture attention could induce illusory conjunctions in the peripheral areas. For example humans have a particularly white sclera, which provides a distinct contrast from the black of the iris. This would therefore capture attention similar to the Gabor patches of Carrasco et al. (2004) and reduce the perception of other facial elements in neighbouring faces.

The importance of the illusory conjunction to group perception is that at any one time the focus of attention will be on only one of the group members. This could lead to an increased risk of misinterpreting the signals of individuals situated outside the attentional window. If the number of individuals located in the peripheral field were to increase then it is likely that the risk of making a mistake, by misattributing the features or expressions of one individual onto another, would also increase. Factors such as repetition and reflection within faces could actually be detrimental in detecting intentional agents within group situations as they provide a means for redundancy of information that could actually increase the chance of illusory conjunctions.

Despite the evidence for an attentional window, results from multiple object tracking and the classic experiments of Sperling (1960) provide evidence that the attentional window might not be limited to focusing on only one area at a time. Multiple-object tracking, provides evidence of a broader attentional focus rather than the idea of an attentional spotlight. In multiple object-tracking participants have to track the movements of objects around a computer screen, in total no more than five objects can be tracked accurately. This suggests that there might be a limit in capacity for tracking (Pylyshyn & Storm, 1988; Cavanagh & Alvarez, 2005). The evidence provided from multiple object tracking studies could suggest that movement, a process that could elicit responses from the collicular visual pathways, might prove significant in rapidly attracting attention.

Sperling (1960) demonstrated that in brief presentations of 200ms there is a limit to the number of items that can be recalled. Sperling showed that in whole reports where participants had to recall all the digits or letters that were presented to them, there was a limit of between 4 and 5 items that could be accurately recalled. However if when cued by a tone to report only on a line of letters, the participants were able to do so, even if they did not know before hand which row was going to be selected. Again in this condition there was a limit of 4 to 5 letters that could be accurately recalled. So although the letters might not have been the focus of attention the information was still available for later processing. This suggests that although the attentional window might not have been able to cover all the information presented there was still post stimulus ability to retrieve information by redirecting the focus of attention.

The experiments of Sperling (1960) and of multiple-object-tracking (Cavanagh & Alvarez, 2005) suggest that there are limits either in perception or processing that constrain the number of objects that can be actively identified or tracked. As the investigation of social group size requires an ability to quantify objects, the subject of memory limits and innate abilities to quantify objects will be briefly outlined.

8.6 Magic numbers and memory limits

One explanation for the observed cognitive constraints on the ability to maintain large group sizes could be that of memory limitations. In recent years there have been many 'magic numbers' put forward as a figure for the cognitive limit in the number of pieces of information that can be stored in the working memory, these limits range from 4 to 7 pieces of information (Cowan 2000; Sperling, 1960; Miller 1956). This storage capacity is an important factor that has to be examined when considering the possibility of any association between attention and group size. Miller (1956) suggested that there was limit to the number of items that could be stored in the short-term memory; this number he suggested was 7 items plus or minus 2. This number has since been disputed and various alternatives have since been suggested (Cowan 2000; Broadbent 1975; Henderson 1972).

Henderson (1972) evaluated previous studies on memory recall and suggested that there was a cognitive limit of four items, however Henderson went on to say that it is possible that if there is a capacity limit it could vary for different stimulus and therefore be task specific. Verbal and auditory memory are considered separate from the visual memory, this is in accordance with Baddeley's visual-spatial sketchpad and central executive concept (Baddeley 1993). There could therefore be different cognitive constraints for each type of memory including social memory. Cowan (2000) argues that the limit to short-term memory recall is 4 chunks of information plus or minus one. Cowan supports his claim stating that during the recall of information from the long-term memory, for example naming the colours of the rainbow or countries of Europe as per experiments conducted by Broadbent (1975), subjects will recall information in chunks of three to four items.

However the focus of attention might be the limiting factor in that only four chunks of information can be processed at any one particular time. Bachelder (2000) suggested that the probability of success in memory tasks decreases in an ogive distribution with an increase in the number of items that have to be recollected. So when looking at the presence of small free forming social groups there could be an attentional limitation to the number of individuals that can be tracked at any one moment.

Finally, evidence from hunter-gatherer tribes that do not possess a language for numbers show impoverished performance in identifying quantities greater than 2 or 3 (Pica et al., 2004; Gordon, 2004, Gelman & Gallistel, 2004). Members of the Pirahã tribe show good accuracy in matching images containing various quantities of elements if they are within the range of 2 or 3 items however performance declines rapidly as the numbers increase to 8 to 10 items (Gordon, 2004). The Pirahã have no language for numbers greater than 2 and adopt the "one-two-many" approach to counting, the poor performance on the number matching tasks are in line with the psychophysical conclusions of Weber (1846) with error rates and size discrimination occurring at threshold intervals. For example amongst numerate participants there is a longer processing time required for discriminating whether 3 > 2 than 5 > 2 (Gelman & Gallistel, 2004). The importance of these studies is that tribes that do not have a mathematical language are not relying on a top-down categorical process but on immediate bottom-up serial comparisons.

To summarise, the following factors need to be considered in the examination of visual constraints on free forming social group size:

1) The properties of the target stimulus, contrast, reflection, repetition
2) The physiology of the retina and representations of the visual field in the striate cortex.
3) Visual attention and the way in which features are bound together.
4) Memory constraints and the perception of quantities.

The following experiments will focus primarily on attentional aspects and the properties of the stimuli. The other factors are then discussed in relation to these attentional aspects.

8.7 Aims

The aims of the following two experiments are to examine the perception of social groups guided by the results of the previous experiments. The first experiment is a more externally valid experiment that examines the subjective perceptions of participants towards some life-sized stimuli presented on a washing line set up. The experiment is designed to examine the effects of faces on the size of the attentional window and how many figures can be accommodated at different eccentricities. In particular the aim is to ascertain whether faces draw attention in a way that may shrink the attentional window in accord with predictions from the research on optimal group size. The second experiment has more internal validity and is a computer based experiment looking at change detection and the effects of type of stimuli by comparing faces, jumbled faces and phone boxes. On the basis of prior research it might be expected that the faces will attract attention more strongly than other non-face objects and either shrink the attentional window or increase the identification of changes (Farah et al., 1998; Tanaka & Sengco, 1997).

The purpose of the following experiment was to begin exploring the issues surrounding face perception within the context of social groups. The two main features that were focused on were the mouth and the eyes as these are the two features that showed the greatest difference in the early perception experiments.

8.8 Part 1: The washing line experiment: the effect of repeated faces on the attentional window

8.8.1 Method

8.8.1.1 Materials

The stimuli comprised of life size printouts of the researcher that were 65cm wide by 180cm long (see Figure 8.1). These were hooked over a washing line so that the images were hung to look as if they were standing naturally. The images consisted of pictures of the researcher, looking straight ahead with a neutral expression. The figures were wearing a shirt with a pale blue repeated check pattern; this was to act as a control to the face reports. The figures were all identical in order to avoid any perceptual biases based on subjective preference. All images were printed in colour using a HP Designjet 120nr poster printer. Behind the images white sheets were hung to obliterate any shadows or background objects. Lines were placed on the floor using blue electrical tape at distances of 1m, 3m and 5m. The average light intensity of the room of was 2.4 Lux with a range of 0.52 Lux (minimum 2.15 Lux and maximum 2.67 Lux).

A questionnaire was devised to record the subjective views of the participants. The questionnaire asked participants to rate on a 7-point scale how clearly they could see the faces on the end figures, the shirt on the end figures and the face on the fixation figure. Participants would indicate a rating of 1 if the images were not clear at all and a score of 7 if the images were perfectly clear. Additional questions asked participants if they could see the eyes and the mouth on the end figures to see if one feature proved more salient. As the questionnaire was looking at subjective responses the participants were allowed to add their own comments to the response sheet describing any biases they felt or any unusual visual disruptions. See Appendix B for example of the questionnaire.

8.8.1.2 Participants

An opportunistic sample of 56 participants, 23 male and 33 female, were recruited from the University of Gloucestershire campus. All participants declared that they had normal or corrected vision. All participants provided full consent to take part in the experiment; the experiment was explained as being a test of peripheral vision and at the end of the experiment the participants were fully debriefed.

8.8.1.3 Design/ Procedure

Participants were asked to stand at one of three distances 1m, 3m and 5m. These distances allowed for individual variations in eyesight to be taken into consideration. The distances were selected so that the images would remain in the range of normal high acuity vision, i.e. within the 6m of normal 20/20 vision. The participant was positioned in front of the central figure and asked to "*fixate on a feature that they would look at if they were having a conversation with the figure*". The participant was required to fixate on this point throughout the entire experimental procedure. Under each condition the participant was read a series of questions and given the chance to describe what they can or cannot see within their visual field. The conditions were (see Figure 8.1): 3 images in a row side by side (condition A), 3 images spaced one body width apart with intermediate face images positioned in-between (Condition B), 3 images in a row spaced one body width apart (Condition C).

For each of the conditions and distances the eccentricity of the peripheral images was calculated (Table 8.1). The eccentricity in this experiment was calculated from the distance between the centre points of the fixation and end figures and the distance the participant was standing from the central fixation figure. The eccentricity of the target stimuli from central fixation relates to the number of degrees from the fovea that the target is presented. This is therefore a useful measure in identifying any effects caused by blind spots and peripheral vision.

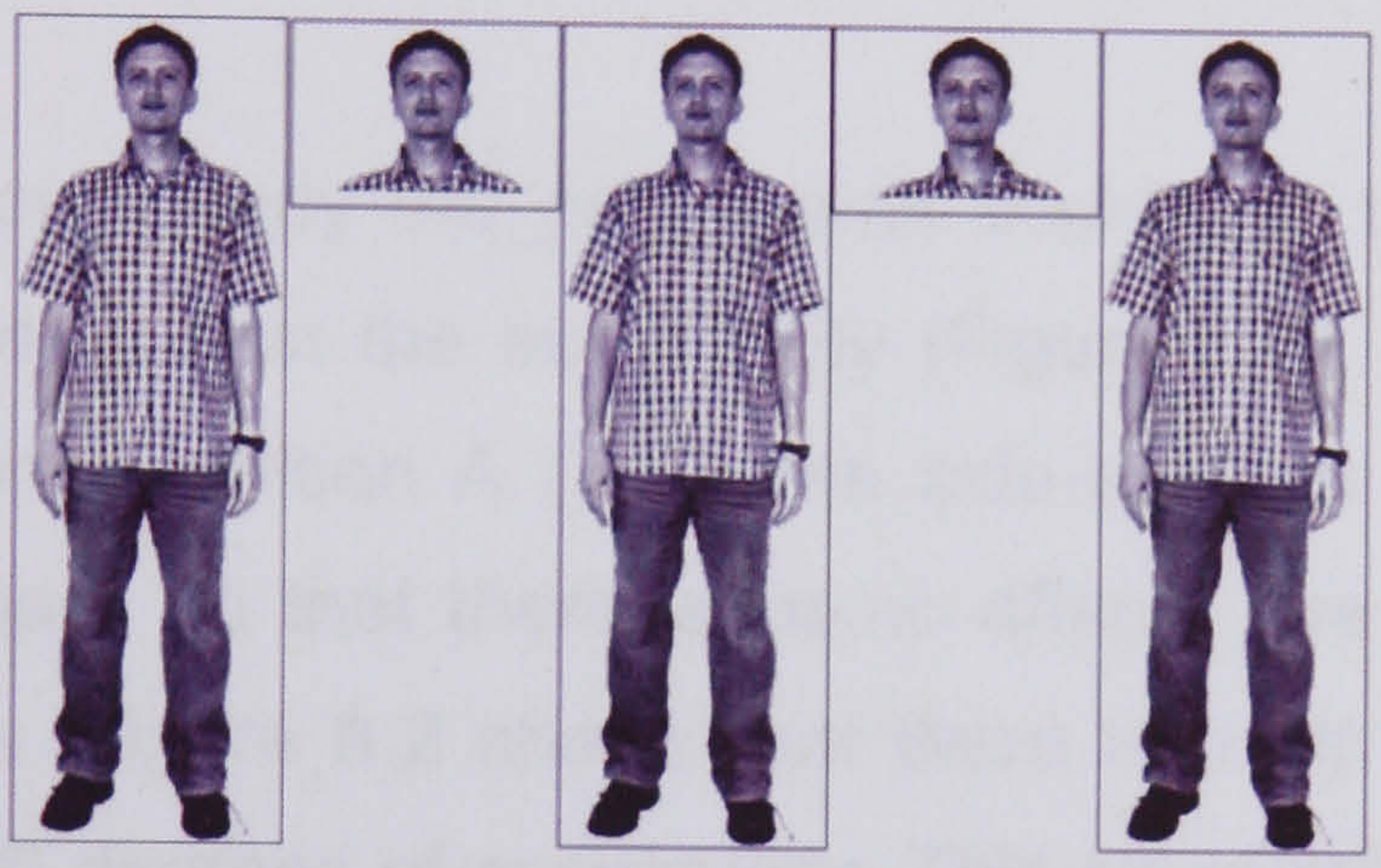
Table 8.1: Stimulus eccentricity and condition

Condition	Distance	Eccentricity (degrees)
A	1	31.79
A	3	11.68
A	5	7.07
B & C	1	51.12
B & C	3	22.46
B & C	5	13.96

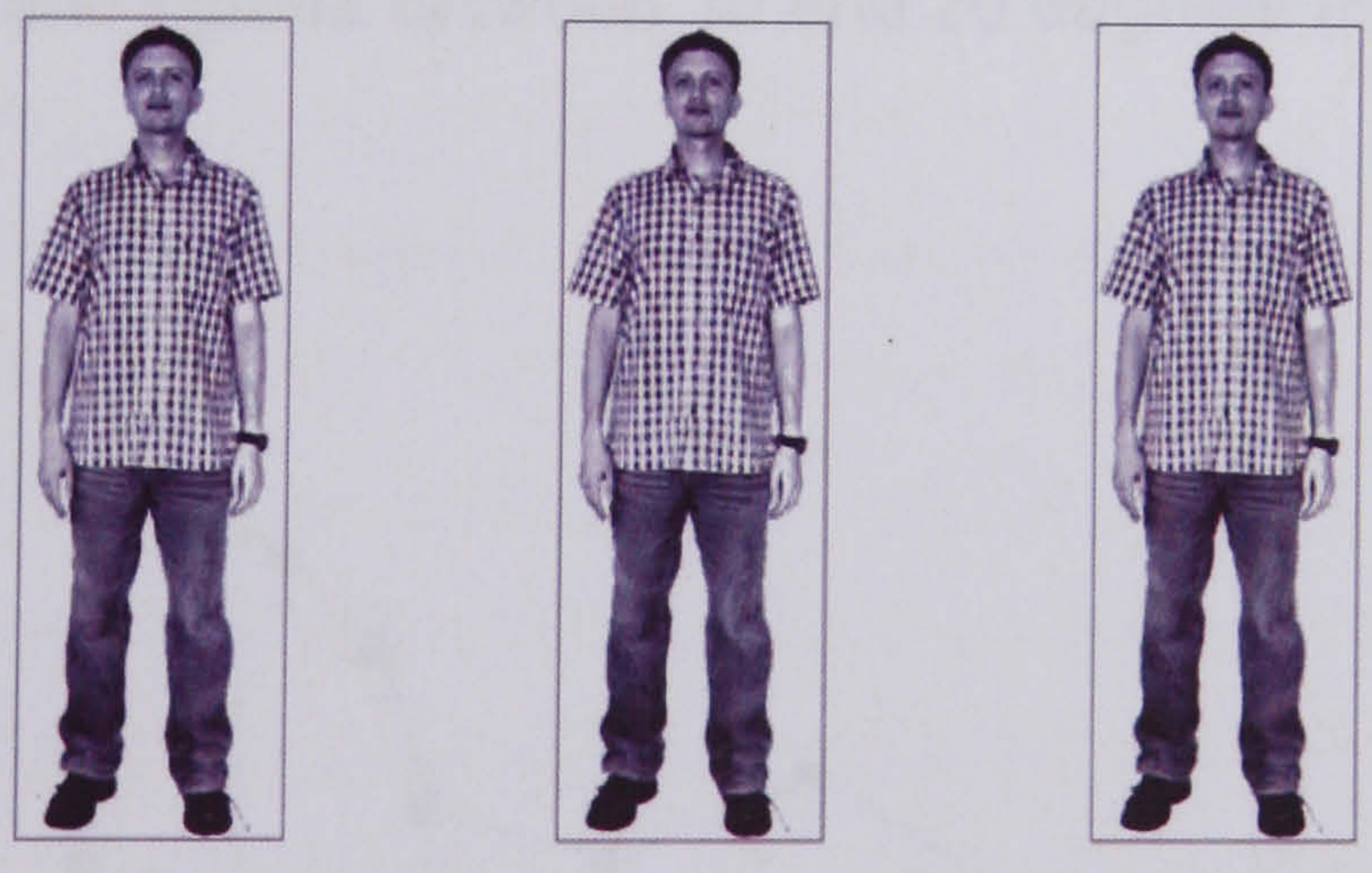
The first four questions addressed whether the participant could see the eyes, nose, or face of the end figures. If a participant had a bias towards one side (i.e. one figure) then this was also noted. These questions were in the form of a yes or no, participants were allowed to elaborate if they were uncertain about what they could see. The second set of questions was based upon a Likert scale. On a scale of 1 to 7 with 7 being VERY CLEAR and 1 being NOT VERY CLEAR they were asked to rate the clarity of the faces of the end figures, the shirts on the end figures and the face that they were fixating upon. This was repeated for all conditions, the order of the trials was randomised to eliminate any priming or practise effects. Prior to each trial the participants were given, as much time as they felt they needed to focus exclusively on the central figure's face. Once they were comfortable they were asked the questions and given as much time as they felt they needed to describe what they could or could not see. Throughout the experiments participants were asked if they were aware of the end figures. The experiment took between 20 and 25 minutes in total. It is expected that if faces capture attention and narrow the attentional window, then there will be higher ratings of clarity by participants for the end figures in conditions A and C.

Although all responses are subjective and based on the participants' descriptions, some participants requested a change to their responses at the end of the experiment after debriefing. The data used are only those responses obtained during the experiment in order to eliminate any 'good participant' effects. The participants were notified that the data from during the experiment would be used but that their changes in response would be noted.

Condition A: 3 figures side-by-side,



Condition B: 3 figures spaced by intermediate faces



Condition C: 3 figures spaced apart at same distances as in Condition B but without intermediate faces

Figure 8.1: Summary of the three figure presentations, Condition A, B and C.

8.8.1.4 Analysis

The research procedure is a within participants design where all participants complete all conditions, the data were therefore analysed using repeated measures two-way ANOVAs or repeated measures one-way ANOVAS where appropriate. Data that are not parametric were analysed using non-parametric tests that were suitable for the data type.

8.8.2 Results

8.8.2.1 The effect of eccentricity on ratings of clarity

The ratings for how clearly the participants could see the face of the end figure were plotted against the eccentricity (Figure 8.2). The measurements were obtained from condition A (3 figures side-by-side) and condition C (3 figures spaced apart) so that there were no effects due to the presence of intermediate faces. Figure 8.2 shows that there is a dip in the mean rating between 10 and 20 degrees of eccentricity. This could reflect the presence of the blind spot. The blind spot could be interfering with the clarity of the perception of the end faces. Similarly there is a dip in the ratings of clarity for the shirts on the end figures between 10 and 20 degrees (Figure 8.3).

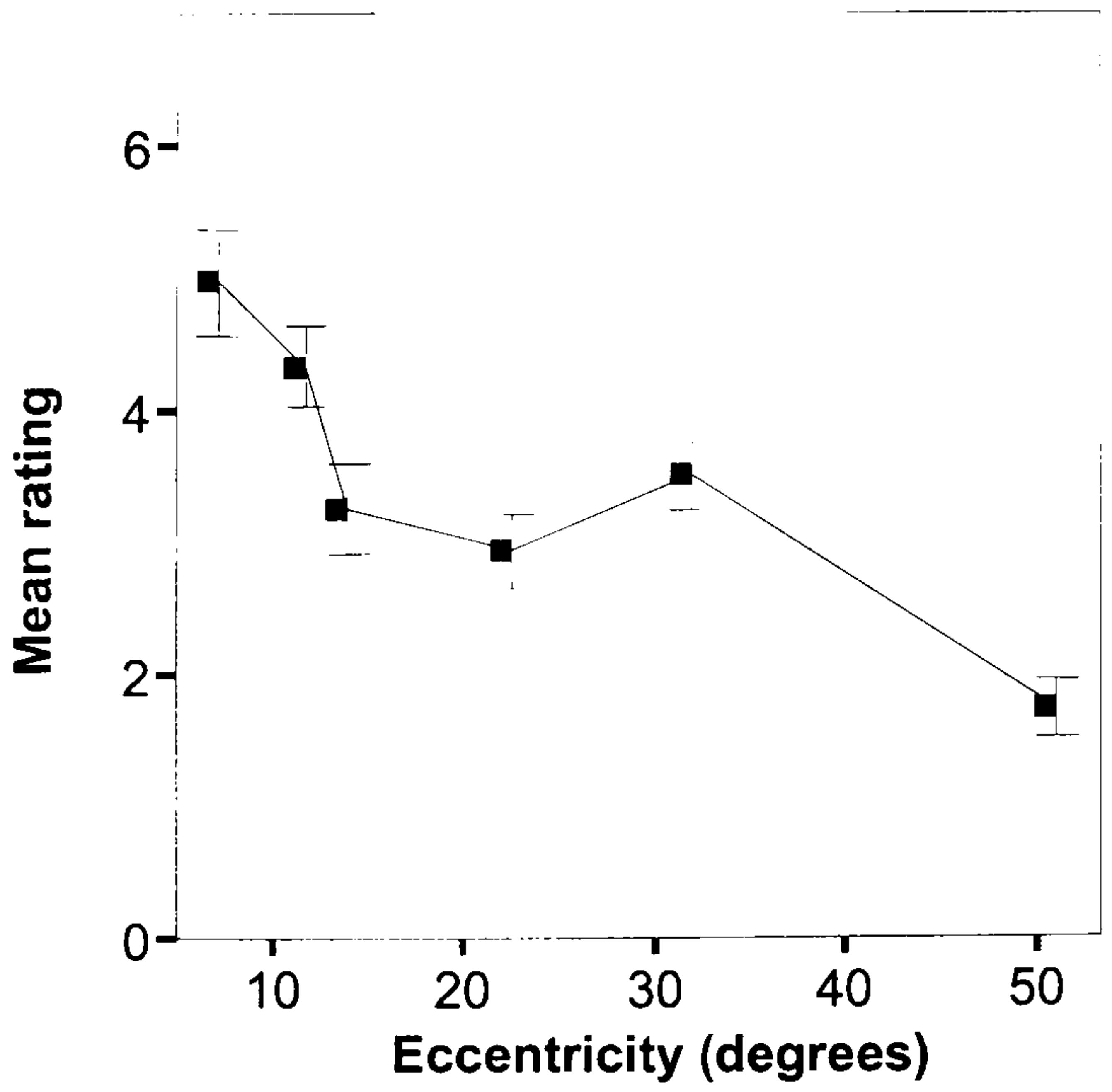


Figure 8.2: The effect of eccentricity on the perception of the faces of the end figures (Rating: 1 = not clear and 7 = very clear). Error bars represent the 95% confidence interval.

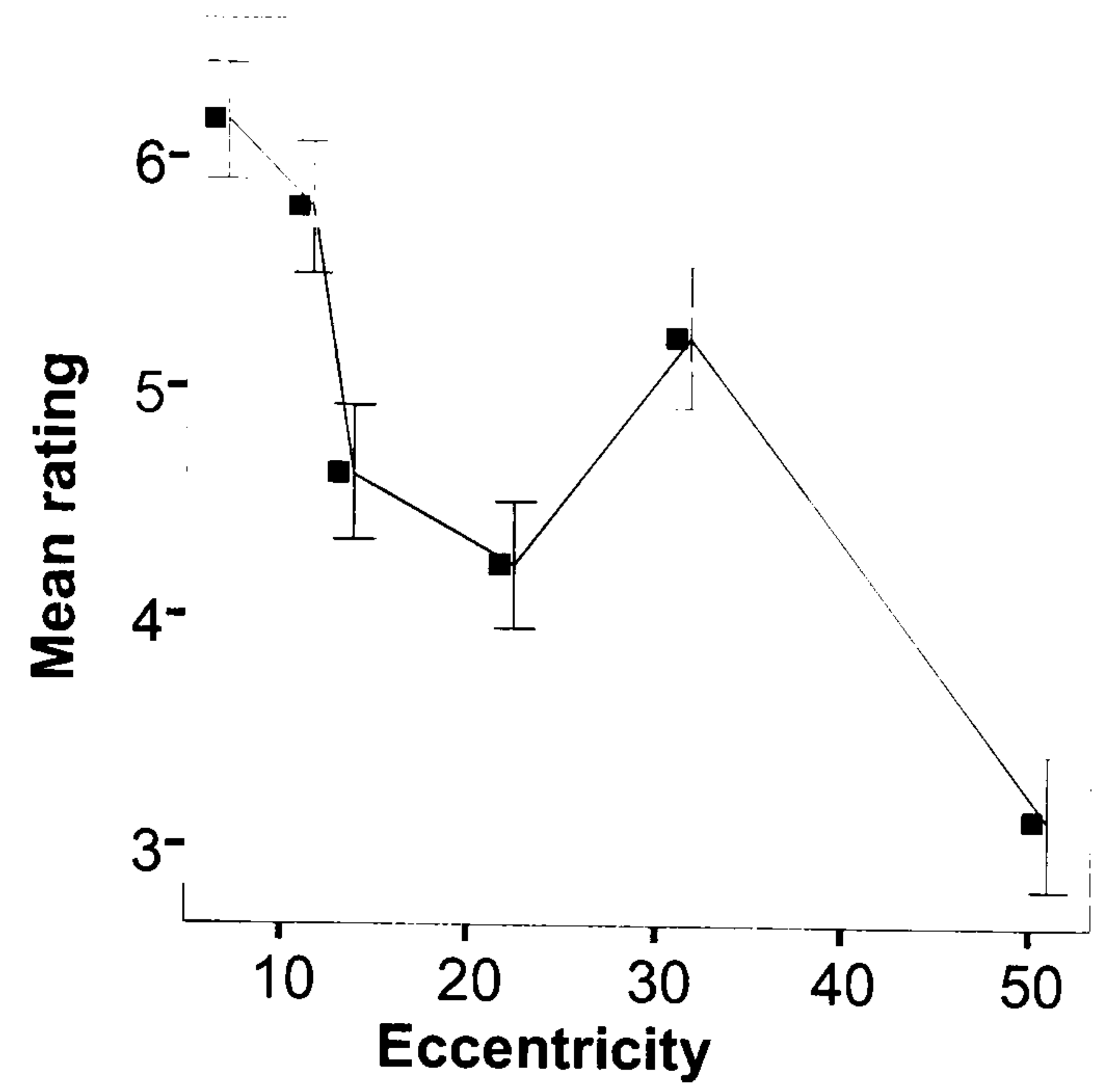


Figure 8.3: The effect of eccentricity on the perception of the shirts of the end figures (Rating: 1 = not clear and 7 = very clear). Error bars represent the 95% confidence interval.

8.8.2.2 The effect of intermediate faces on the ratings of clarity of the end faces.

A within participants repeated measures 2 x 3 (presence of intermediate face x eccentricity) ANOVA was conducted on the participants ratings of clarity of the end faces (conditions B and C). The eccentricity had a highly significant main effect on the participants' rating of the faces of the end figures ($F_{2,110}$ = 87.627, $p < 0.001$, $\eta^2 = 0.614$) with higher ratings of clarity at smaller eccentricities. There was a highly significant effect due to the presence or absence of an intermediate face ($F_{1,110}$ = 35.623, $p < 0.001$, $\eta^2 = 0.393$). The presence of an intermediate face resulted in a reduced rating of clarity of the faces on the end figures (see Figure 8.4). The interaction between the change in eccentricity and the presence or absence of the intermediate faces was also highly significant but with a weak main effect ($F_{2,110}$ = 5.020, $p = 0.008$, η^2 = 0.084).

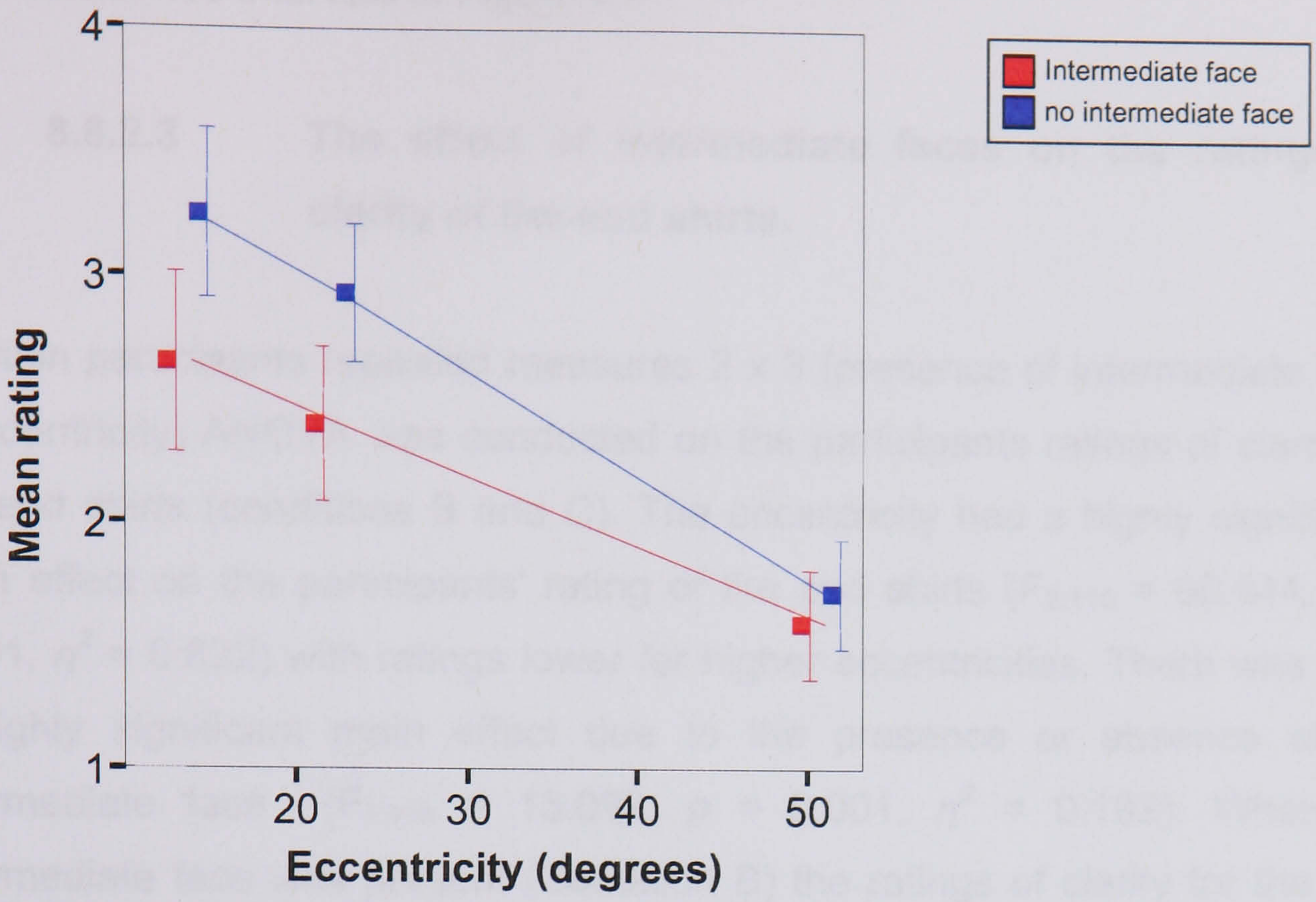


Figure 8.4: the effect of intermediate faces on clarity of report on end faces (Rating: 1 = not clear and 7 = very clear). Error bars represent the 95% confidence intervals.

Table 8.2: Mean clarity ratings for the faces of the end faces

Condition	Mean	SD
Intermediate face		
27.86°	2.64	1.35
44.91°	2.39	1.17
102.23°	1.59	0.83
No intermediate face		
27.86°	3.25	1.30
44.91°	2.93	1.04
102.23°	1.71	0.82

The means and standard deviations for the ratings of the faces of the end figures are shown in table 8.2. As shown in figure 3 and figure 4, there is a decline in the ratings of clarity with an increase in visual angle. This suggests that at the distance of 5m, an eccentricity of 13.96 degrees, participants can see the images more clearly as the figures all fall within the high acuity field of vision. However, the presence of the intermediate faces appears to have a detrimental effect on the peripheral vision despite the constancy in the visual angle of the end figure in relation to the participant. When the eccentricity of the end figure is increased in relation to the participant there is a decrease combined with a greater overlap of the ratings, as shown by the overlap of the 95% confidence intervals in Figure 8.4.

8.8.2.3 The effect of intermediate faces on the ratings of clarity of the end shirts.

A within participants repeated measures 2 x 3 (presence of intermediate face x eccentricity) ANOVA was conducted on the participants ratings of clarity of the end shirts (conditions B and C). The eccentricity had a highly significant main effect on the participants' rating of the end shirts ($F_{2,110} = 90.644$, $p < 0.001$, $\eta^2 = 0.622$) with ratings lower for higher eccentricities. There was also a highly significant main effect due to the presence or absence of an intermediate face ($F_{1,110} = 13.092$, $p = 0.001$, $\eta^2 = 0.192$). When an intermediate face was present (Condition B) the ratings of clarity for the end shirts was significantly reduced. However, when the interaction between the two variables were tested there was no significant interaction between the ratings of the end shirt and the eccentricity ($F_{2,110} = 0.856$, $p = 0.428$, $\eta^2 = 0.015$). Figure 8.5 shows that although there was a significant difference between ratings of the end shirt when an intermediate figure was present the overall scores remain high compared to those of the ratings for the end faces in Figure 8.4. The means and standard deviations for the ratings of the shirts of the end figures are shown in Table 8.3.

Table 8.3: Mean clarity ratings for the shirts of the end figures

Condition	Mean	SD
Intermediate face		
27.86°	4.43	1.59
44.91°	4.07	1.46
102.23°	3.04	1.50
No intermediate face		
27.86°	4.82	1.56
44.91°	4.38	1.41
102.23°	3.21	1.67

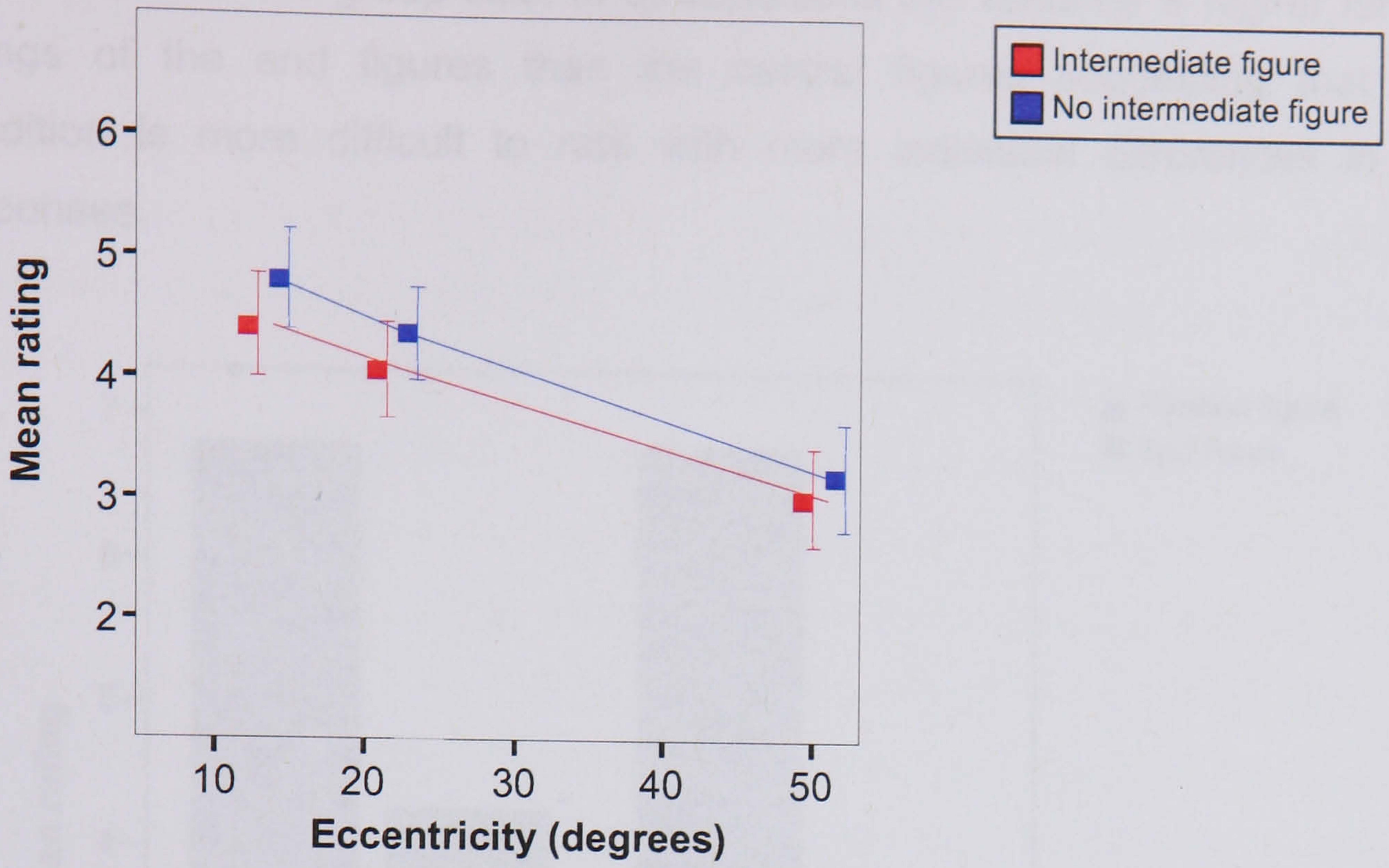


Figure 8.5: the effect of intermediate faces on clarity of report for the shirts of the end figures (Rating: 1 = not clear and 7 = very clear). Error bars represent the 95% confidence intervals.

8.8.2.4 Comparison between group sizes and between ratings of the fixation figure and end figures

Although distinct trends and differences have been highlighted, the results need to be compared with a control stimulus; in this experiment the control was the fixation figure. The mean ratings for the faces of the *fixation* figures are 6.8 for group sizes of 3 figures and 6.8 for group sizes of 5 figures. The mean ratings for the faces of the end figures are 4.3 for group sizes of 3 figures and 2.2 for group sizes of 5 figures. Group sizes of 3 are significantly clearer to see than those of 5 ($F_{1,167} = 31.810$, $p < 0.001$, $\eta^2 = 0.160$). The main effect between the ratings for the end figure and the ratings for the fixation figure were highly significant ($F_{1,167} = 2083.75$, $p < 0.001$, $\eta^2 = 0.926$). There was a highly significant interaction between group size and type of figure rated ($F_{1,167} = 39.511$, $p < 0.001$, $\eta^2 = 0.191$). Although group size in general has an effect on the ratings it has little effect on the reported clarity of the fixation figure as shown in Figure 8.6, which retains a high average score of approximately 6.8 out of a possible 7 throughout (Table 4). This indicates that the reduction in scores observed in the end faces is more strongly associated with the group size. In all conditions the variance is higher for the ratings of the end figures than the central figures suggesting that this condition is more difficult to rate with more individual differences in the responses.

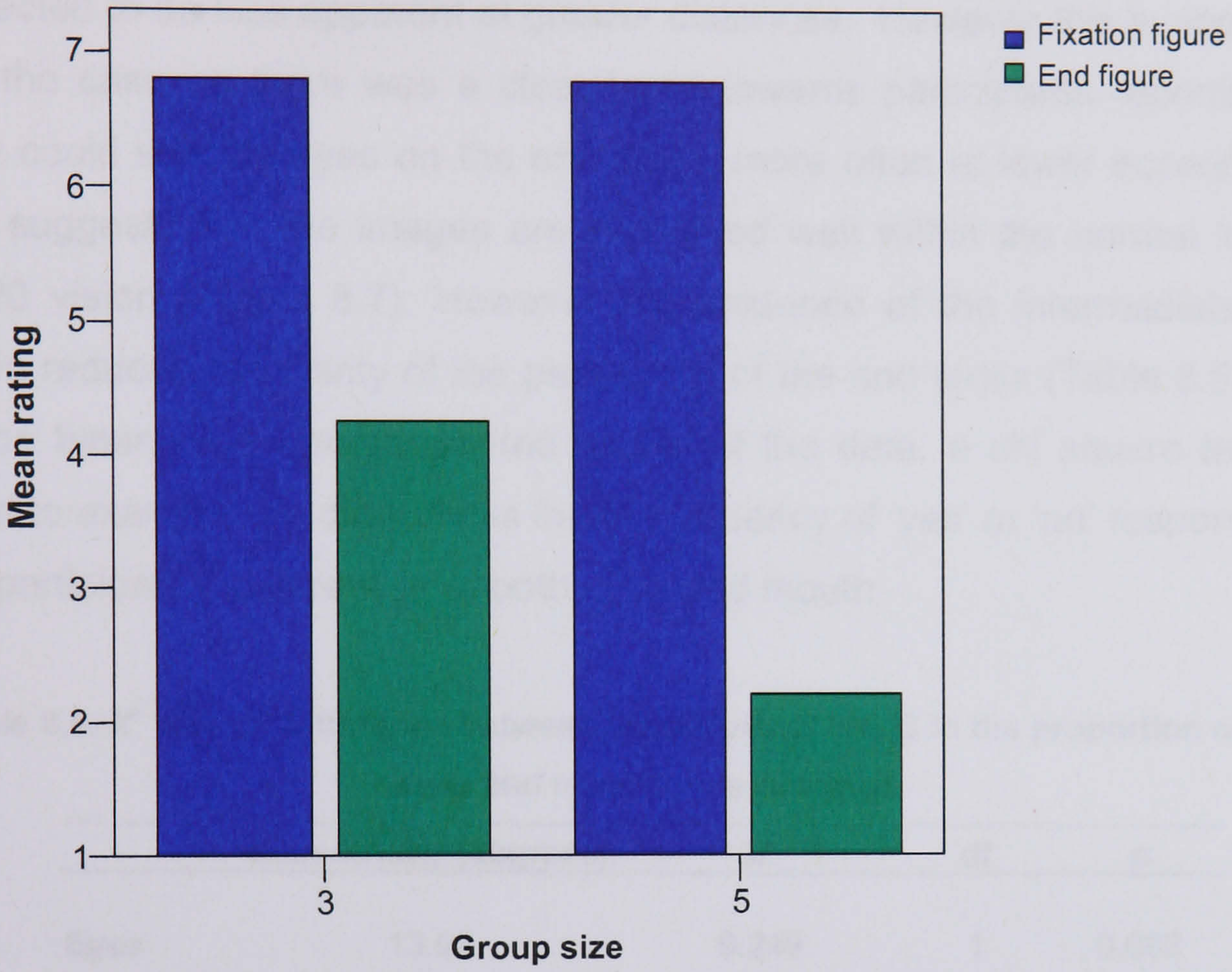


Figure 8.6: the effect of group size on report of end face and fixation figures (Mean rating: 1 = not clear and 7 = very clear).

Table 8.4: mean ratings and standard deviations for faces of the end figure and fixation figure for different group sizes

Condition	Mean	SD
Group size = 5		
End figure	2.21	1.22
Fixation figure	6.79	0.57
Group size = 3		
End figure	2.63	1.26
Fixation figure	6.77	0.61

8.8.2.5 Analysis of participants' reports of the presence of the eyes and mouth

In this experiment lower eccentricity is related to participants standing at greater distances from the fixation figure, therefore depending on individual variations in normal eyesight the fine details of the eyes and mouth would be expected to be less apparent at greater distances. However this is apparently not the case as there was a clear trend towards participants reporting that they could see the eyes on the end figure more often at lower eccentricities, this suggests that the images are presented well within the normal limits of 20/20 vision (Figure 8.7). However the presence of the intermediate faces again reduced the clarity of the perception of the end faces (Table 8.5). Due to the binary and non-parametric nature of the data, a chi square test was used to examine the differences in the frequency of 'yes' or 'no' responses for the participants' awareness of both eyes and mouth.

Table 8.5: X^2 test for difference between conditions B and C in the proportion of times eyes and mouth were detected

	Eccentricity (degrees)	X^2	df	p
Eyes	13.93	9.249	1	0.002
	22.46	6.502	1	0.011
	51.12	1.884	1	0.170
Mouth	13.93	4.094	1	0.043
	22.46	1.465	1	0.226
	52.12	0.152	1	0.696

The mouth was detected more frequently when there were no intermediate faces but this was only significant at an eccentricity of 13.93° (Table 8.5). By comparing the trends in Figures 8.7 and 8.7 it is noticeable that the mouth was detected less frequently than the eyes at lower eccentricities. This suggests that the eyes are more salient and capture attention. There is a sharp decline in the proportion of times the mouth is reported at an eccentricity of 22.46°. This could suggest interference from the blind spot on less salient features or that the eyes only are capturing the window.

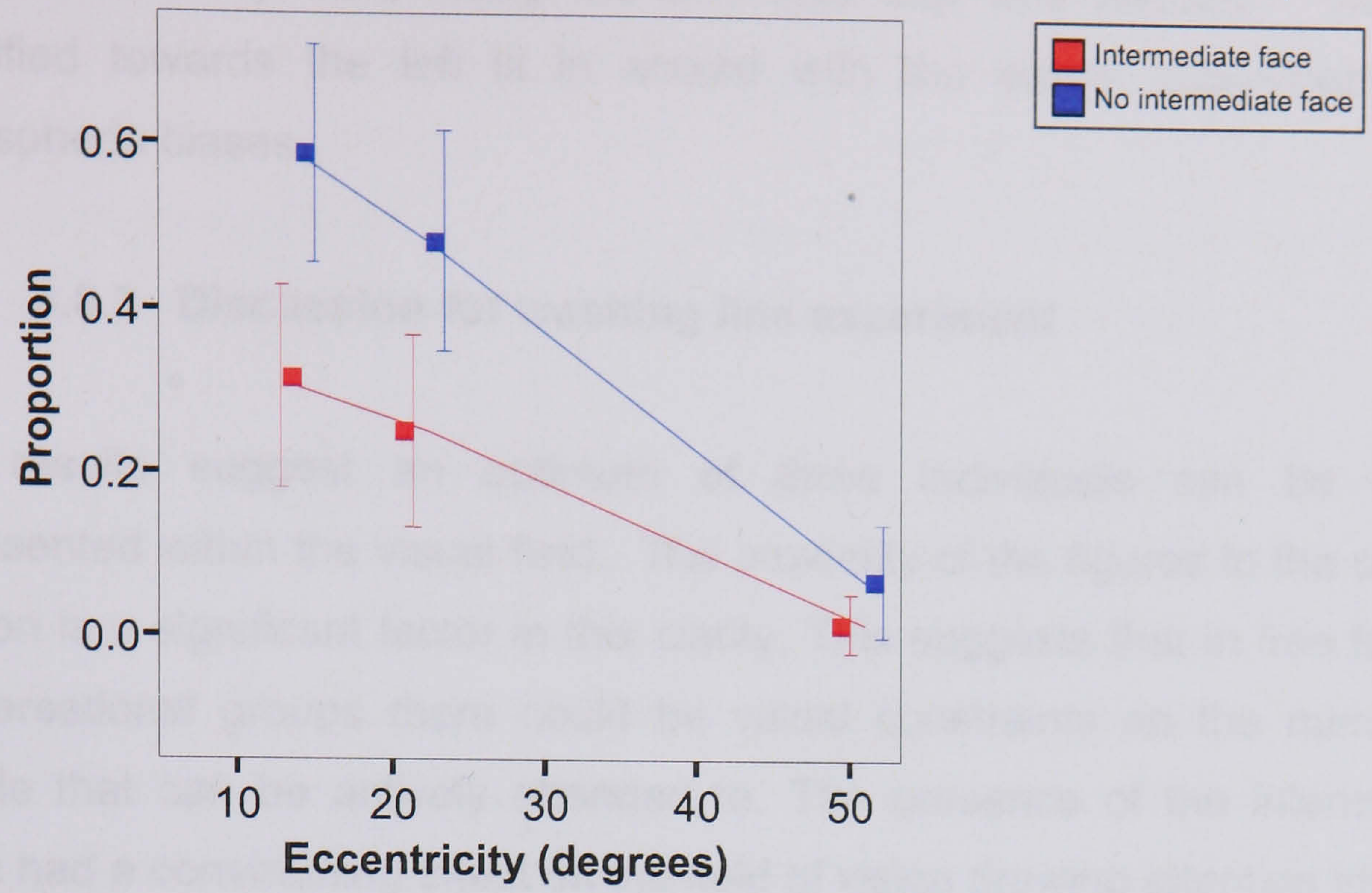


Figure 8.7: The proportion of times the participant is aware of the presence of the eyes on the end figures. Error bars represent the 95% confidence intervals.

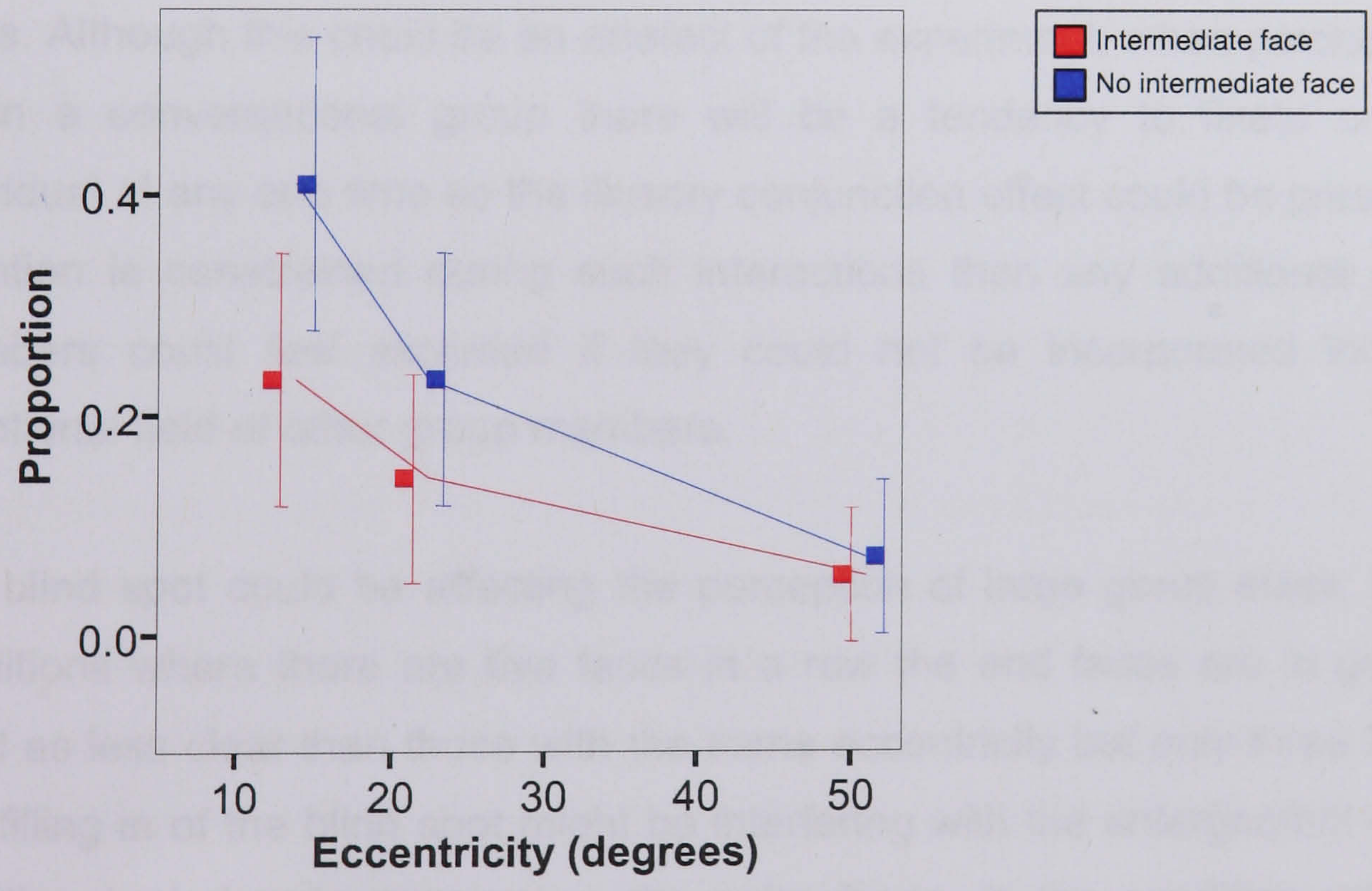


Figure 8.8: The proportion of times the participant is aware of the presence of the mouth on the end figures. Error bars represent the 95% confidence intervals.

From the additional responses and feedback it was noted that 20 of the participants reported a bias towards the left visual field and 5 participants reported a bias to the right visual field. In these circumstances the participants claimed that they were rating the end face that was clearest. The bias identified towards the left is in accord with the earlier experiments into hemispheric biases.

8.8.3 Discussion for washing line experiment

The results suggest an optimum of three individuals can be clearly represented within the visual field. The proximity of the figures to the point of fixation is a significant factor in this clarity. This suggests that in free forming conversational groups there could be visual constraints on the number of people that can be actively attended to. The presence of the intermediate faces had a constraining effect on the field of vision drawing attention inwards. The flanking figures acted as a type of mask or barrier to actively perceiving the peripheral figures. This could result in participants neglecting the further figures. However, if the central fixation figure is being focused on, i.e. they are being perceived locally within the group the outer faces could become blurred as illusory conjunctions form between the intermediate faces and the end faces. Although this could be an artefact of the experiment, when participating within a conversational group there will be a tendency to fixate on one individual at any one time so the illusory conjunction effect could be present. If attention is constrained during such interactions then any additional group members could feel excluded if they could not be incorporated into the attentional field of other group members.

The blind spot could be affecting the perception of large group sizes, in the conditions where there are five faces in a row the end faces are in general rated as less clear than those with the same eccentricity but only three faces. The filling in of the blind spot might be interfering with the enlargement of the attentional window to encompass the outer faces. In the condition with the same eccentricity but no intermediate faces the blind spot can be adjusted for easily due to the white background, hence there is no problem as there are no features that require binding. Anecdotal evidence comes from participants that felt that when the intermediate faces were present that the end face and intermediate face became one and the same.

However, it has to be noted that not all participants reported this bias in some instances participants found it easier to report the end figures if there were intermediate faces. By increasing the external validity of the experiment there is a loss in the ability to accurately quantify what people are seeing, whether they understood the questions and exactly what they are reporting.

The effect of the intermediate faces highlights the importance of faces in capturing visual attention. Faces contain a lot of configural information and different types of near symmetries both repetitive and reflective. The type of symmetry that is predominantly observed could affect the perception of the group. For example if the faces are seen as a gestalt and processed in a similar way to objects containing reflective symmetry then attention will be focused on identifying the boundaries of the face and therefore reducing the size of the attentional window to a few degrees of the central axis of reflection. If the faces are seen as individual gestalts then there would be serial processing of the rows however if the faces are seen as part of a larger repeated pattern then they would be processed in parallel. The constraining effect of the intermediate faces would be more indicative of a serial approach to processing.

In comparison with the face, the shirts were rated more clearly throughout the experiment. The shirts consisted of a simple repeated check pattern providing redundant information that would make identification of the shirt in the peripheral vision easier than the faces. The highly repetitive nature of the shirt pattern can be processed as a uniform background, the presence of which can be sensed without the need to examine it any detail. Hence once the shirt has been seen, the identification of it on the end figures would follow a top-down approach whereby the participant is already sensitive to it. Conversely in the face detection scenario the participants actively try to pick out detail and features this would provide to be more of a bottom-up approach. Although they are familiarised with the face by asking them to detect individual features the participants are using the same processes that they would utilise in identifying expressions.

In this experiment, the eyes appear to be the more salient of the two facial features examined. This readiness to identify the eyes might suggest that like the shirt there is redundant information and that the eyes are therefore easier to identify. However, as mentioned in the introduction the high contrast nature of the eyes might result in a widening of the attentional window and a kind of multiple-object tracking of a conspicuous homogenous set of stimuli.

In terms of the size of free forming conversational groups there would be considerable benefits in maintaining a smaller group as the inclusion of further group members could limit the intensity of interaction between group members. In conversational groups there is a need to attend to the facial responses of other group members, as this will provide clues not only to their interest but also to their intentions. As reported earlier the average conversational group size is four or less (Dunbar et al. 1995). This would fit well with the results of our experiment where there is significant decline in the detection of faces presented either side of a central 3 figures. These results add another limitation to how human social groups form in addition to the previously identified factor of noise detection.

From an evolutionary perspective this suggests that despite the evolution of language the free forming social group size is still limited by the position and physiology of visual system. However it is important not to oversimplify the role that visual attention plays in group size formation and maintenance. As with the nested letter stimuli used by Navon (1977) in his experiments on global and local perception, so too are the social groups nested. At the most local level of perception is the identification of individual features and expressions on the face that is being attended; next there is the local detection of the face within the group and finally a more global perception of the group as a whole. Although in small numbers there is a limit to the number of faces that are perceived utilising local feature detection as in this experiment, there also has to be a critical point where the local perception of an intimate social group switches to the global perception of a crowd. Therefore the terms local and global perception are highly blurred in social interactions. The ability to adjust the size of the attentional window and switch between perception at local and global levels means that there is great flexibility in the information that the brain picks up and utilises. In addition top-down processes can aid the location of objects and features reducing the need for a greater area of foveal vision. Instead of improving the visual hardware, the human visual system has apparently improved the software as illustrated by the correlations between the size of non-striate cortical areas and social group size in primates (Joffe & Dunbar, 1997).

Although this experiment was intended as a preliminary investigation into individual differences in visual processing of faces within peripheral vision, one of the major limitations is that within a real life scenario the features and bodies would be moving. In this experiment this particular aspect is missing, which, as commented by several participants, lead to either an unnerving feeling of being stared at or the feeling that the peripheral figures were moving. These comments highlight the importance of trying to balance ecological validity with internal validity of experiments. In the second experiment the internal validity is controlled and the type of stimuli are altered in order to identify whether it is the presence of the intermediate faces, the configuration of the face or the eccentricity of the stimulus presentation that results in preferential reports for smaller social group sizes.

8.9 Part 2: Change detection in computer generated facial and non-facial stimuli at varying eccentricities

In the following study the methodology from the washing line experiment was recreated using a computer to create a more internally valid experiment and to test for the saliency of specific changes at different positions within the visual field. This experiment examines further the importance of stimulus type to see if faces were special in the perception of social group sizes. The visual field within which the change occurred was also considered as in previous experiments this was shown to be a significant factor in accuracy during procedures that involve the rapid presentation of patterned stimuli.

8.9.1 Methods

8.9.1.1 Materials

The computer and experimental area was set up as per the criteria laid out in the methodology chapter. The experimental area was maintained under constant conditions: background light and noise was kept to a minimum.

8.9.1.2 Stimuli

The stimuli consisted of rows of images, these images were either the photo fit faces used in the face perception masking experiment, faces with jumbled features or TARDIS' representing a non-face stimuli while possessing similar properties in terms of high contrast areas, repeated elements and reflected elements (see Figure 8.9).

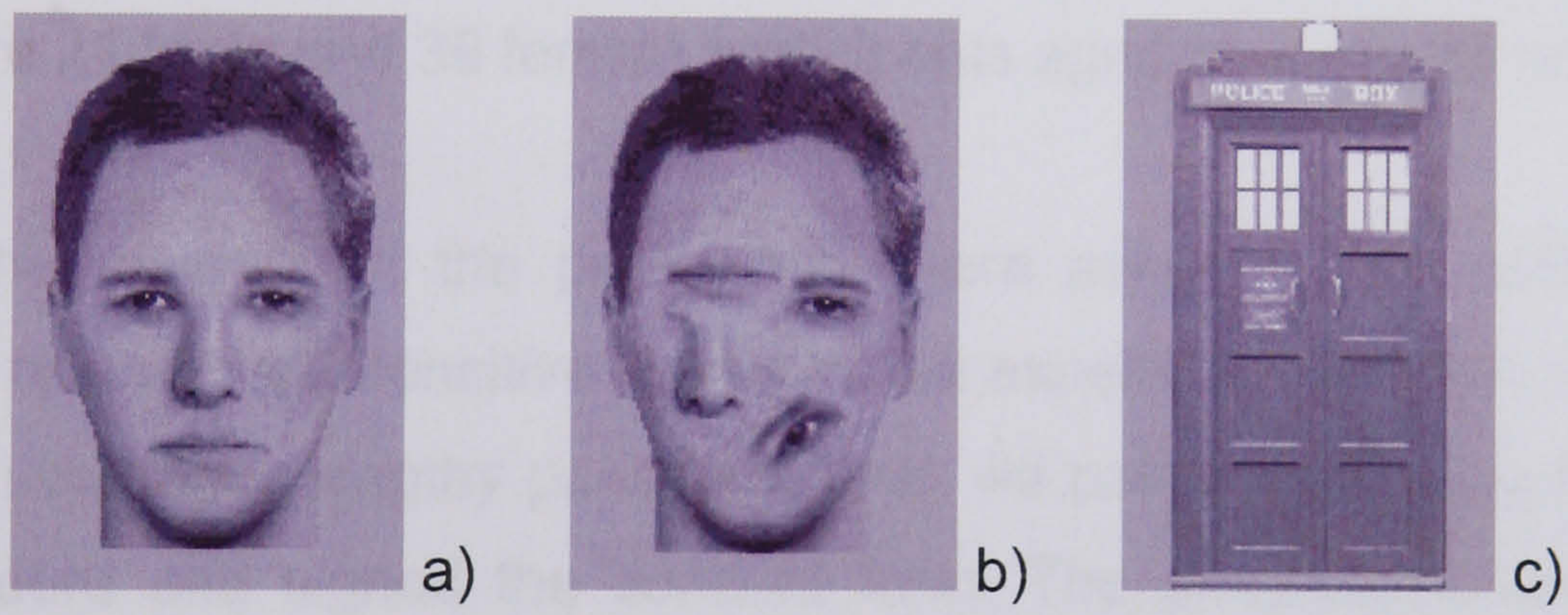

a) b) c)

Figure 8.9: examples the basic images used in creating the test stimuli: a) normal face, b) jumbled face, c) TARDIS.

Changes occurred to the eyes in the faces and the lower row in the windows of the Tardis. The images were presented in rows of 5 or 3 and changes would occur either to the image located on the far left, near left, centre, near right or far right. The rows of 3 images were either presented side by side or with a gap, 1 image width, between them similar to condition C in the washing line experiment. The images were counterbalanced with sets that possessed no change so that there was an equal chance of guessing whether a change occurred or not.

The target area size varied according to the number of images presented. This change in area was accounted for in terms of eccentricity in order to maintain consistency with the previous experiment. Stimulus size was either 8.26° eccentricity for the rows of 3 images, and 13.82° for rows of five images or 3 images presented within the sparse condition. The individual images had an eccentricity of 1.76°. These eccentricities can also be used to reflect the positions where the changes occur, so a change to the central image is within 1.76°, a change to one of the neighbouring (near) images is within 8.26°, and a change to one of the peripheral images occurs within 13.82°. The participants were seated at a distance of between 60 and 70 cm from the screen, the eccentricity was calculated for a distance of 65cm.

8.9.1.3 Participants

An opportunistic sample of 50 participants was obtained from the university campus. All participants were and offered £5 for taking part in the experiment. There were 21 Male and 39 female participants aged between 18 and 40.

Prior to the experiment the participants were asked if they suffered from migraines or any photosensitive illness as the experiment required staring at a computer screen for lengthy periods of time. All participants were happy with the procedure and signed the consent form. The participants were free to withdraw from the experiment at anytime; all participants completed all the trials.

8.9.1.4 Procedure

Participants had to identify whether they saw any change occurring to the image. They were asked to press “1” if there was a change and to press “2” if they thought that there was no change. A practice session consisting of 16 trials allowed participants to become familiar with the procedure. In the practice session the change occurring involved the change of an abstract shape that was easy to detect and one example of each of the test stimuli.

In the main session there were 264 trials, the conditions were counterbalanced so that there was always a 50/ 50 chance of getting a correct answer and so that each stimulus type would appear as frequently in each position. This prevented any advantageous priming or bias towards any one particular target. The reaction times, position of change, correct response, were recorded. Participants were given feedback after each trial in the form of an onscreen percentage correct. This encouraged participants to not guess and to attend as fully as possible to the stimuli.

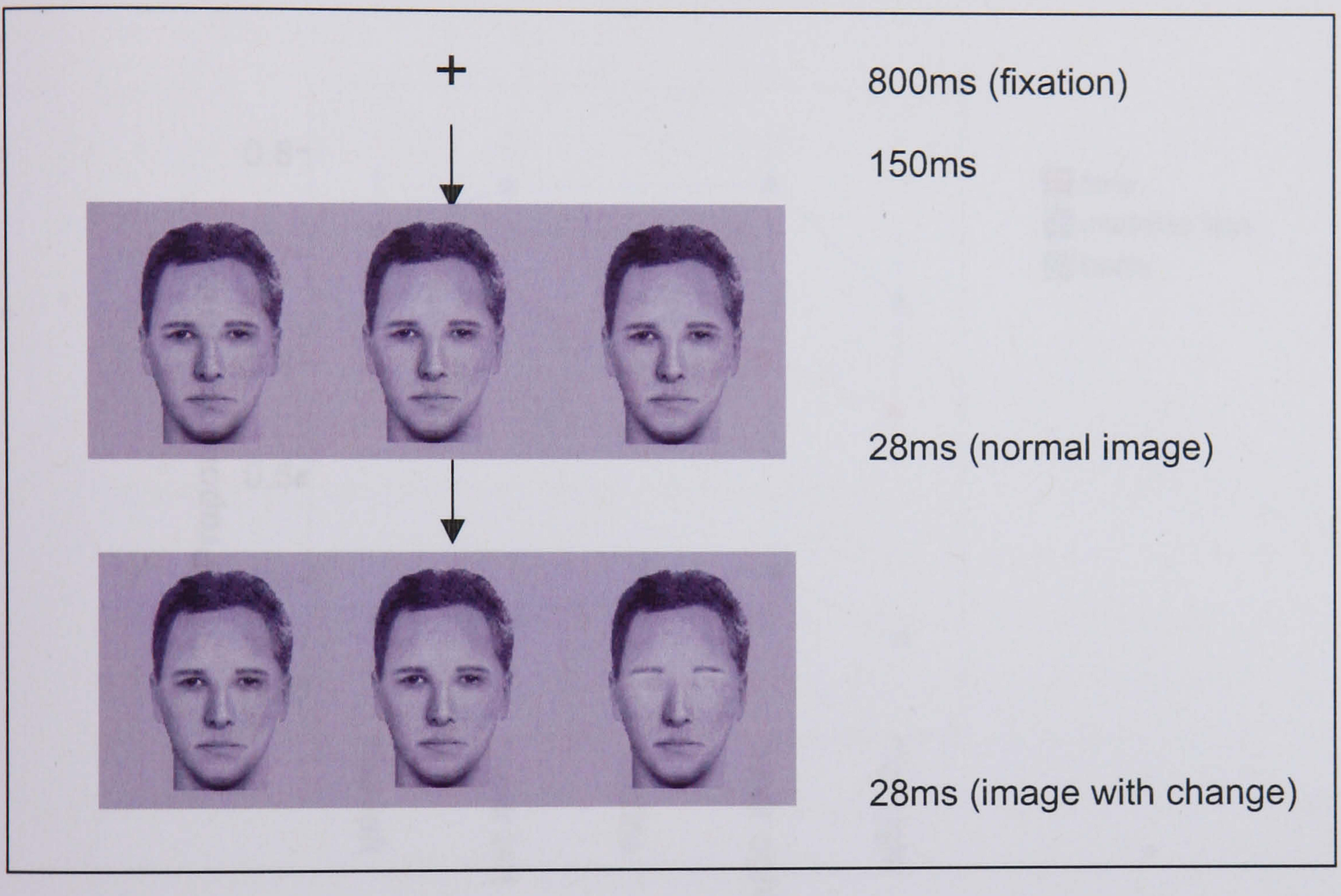


Figure 8.10: Example of how the stimuli were presented in the trials, participants were given a fixation point followed by a row of images with no change and then a target image that may or may not have had a change.

The presentation order of the trials is shown in Figure 8.10. Each set of images appeared for 28ms. This was to prevent any saccadic eye movements or serial processing of the target stimuli. Following each trial a final screen would, remind the participants of which keys they should press. Due to the rapid presentation rate participants were allowed to respond as soon as they saw the change and did not have to wait for the prompt screen to appear.

Halfway through the experiment there was a two-minute break to prevent fatigue within the participants. The complete experiment took approximately 45 minutes. After the experiment the participants were debriefed and told the full purpose of the experiment.

8.9.2 Results

8.9.2.1 The effect of type and position of stimuli

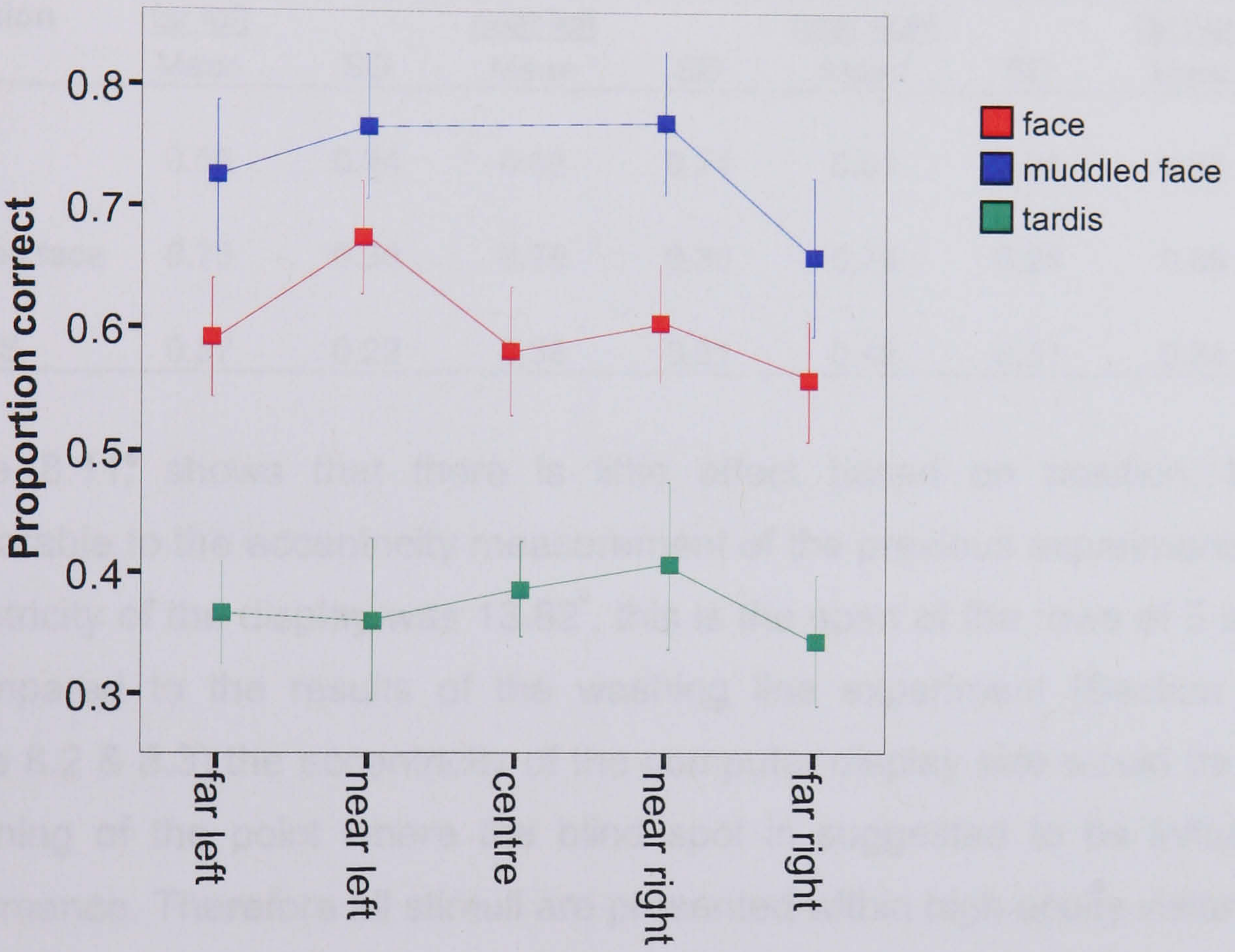


Figure 8.11: mean scores (proportion of correct answers) for each change position under the three conditions.

There was not a significant linear main effect of position of change on the proportion of correct responses ($F_{1,49} = 2.428$, $p = 0.126$, $\eta^2 = 0.047$). However there was a highly significant main effect for a quadratic relationship between position of change and the proportion of trials answered correctly ($F_{1,49} = 9.894$, $p = 0.003$, $\eta^2 = 0.168$), this is best illustrated in the shape of the line for the muddled face in Figure 8.11. There was a highly significant effect on the proportion of responses correct as a result of the type of stimuli ($F_{2,98} = 47.638$, $p < 0.001$, $\eta^2 = 0.493$). Changes occurring to the muddled face appear to be detected more accurately than the normal face and the TARDIS. This suggests that symmetry of the face is not the main factor in the saliency of facial features. There was no significant interaction between the type of stimuli and the position of change on the proportion of correct responses ($F_{6,294} = 0.864$, $p = 0.522$, $\eta^2 = 0.017$). Table 8.6 contains the means and standard deviations for the positions and stimulus conditions used in the experiment.

Table 8.6: Means and standard deviations for correct responses for different stimulus types and position

Condition	far left		near left		near right		far right	
	Mean	SD	Mean	SD	Mean	SD	Mean	**SD**
Face	0.59	0.24	0.68	0.24	0.61	0.24	0.56	0.24
Muddled face	0.73	0.30	0.75	0.30	0.76	0.24	0.66	0.31
TARDIS	0.37	0.22	0.38	0.31	0.42	0.31	0.34	0.24

Figure 8.11, shows that there is little effect based on position, this is comparable to the eccentricity measurement of the previous experiments. The eccentricity of the display was 13.82°, this is the span of the rows of 5 stimuli. If compared to the results of the washing line experiment (Section 8.8.3, Figure 8.2 & 8.3) the eccentricity of the computer display size would be at the beginning of the point where the blind spot is suggested to be influencing performance. Therefore all stimuli are presented within high acuity vision.

8.9.2.2 The effect of distribution

The stimuli were then compared using a 2 X 2 (proximity x stimulus type; Face or TARDIS) ANOVA for differences between the type of stimulus and whether the stimuli were presented close together, i.e. crowded or at one stimuli width apart, i.e. sparsely. The main effect of the type of stimulus was significant ($F_{1,49} = 5.618$, $p = 0.022$, $\eta^2 = 0.103$) with changes occurring to the faces being correctly identified more frequently than the TARDIS stimuli. However there was not a significant main effect for how the stimuli were presented ($F_{1,49} = 0.055$, $p = 0.815$, $\eta^2 = 0.001$). There was not a significant effect due to the interaction between the type of stimulus and how they were presented ($F_{2,49}$ = 2.319, p = 0.134, η^2 = 0.045). This suggests that the whole array was probably encompassed well within the attentional window but that there are still fundamental differences between responses to face stimuli compared with the non-face TARDIS stimuli (Figure 8.12).

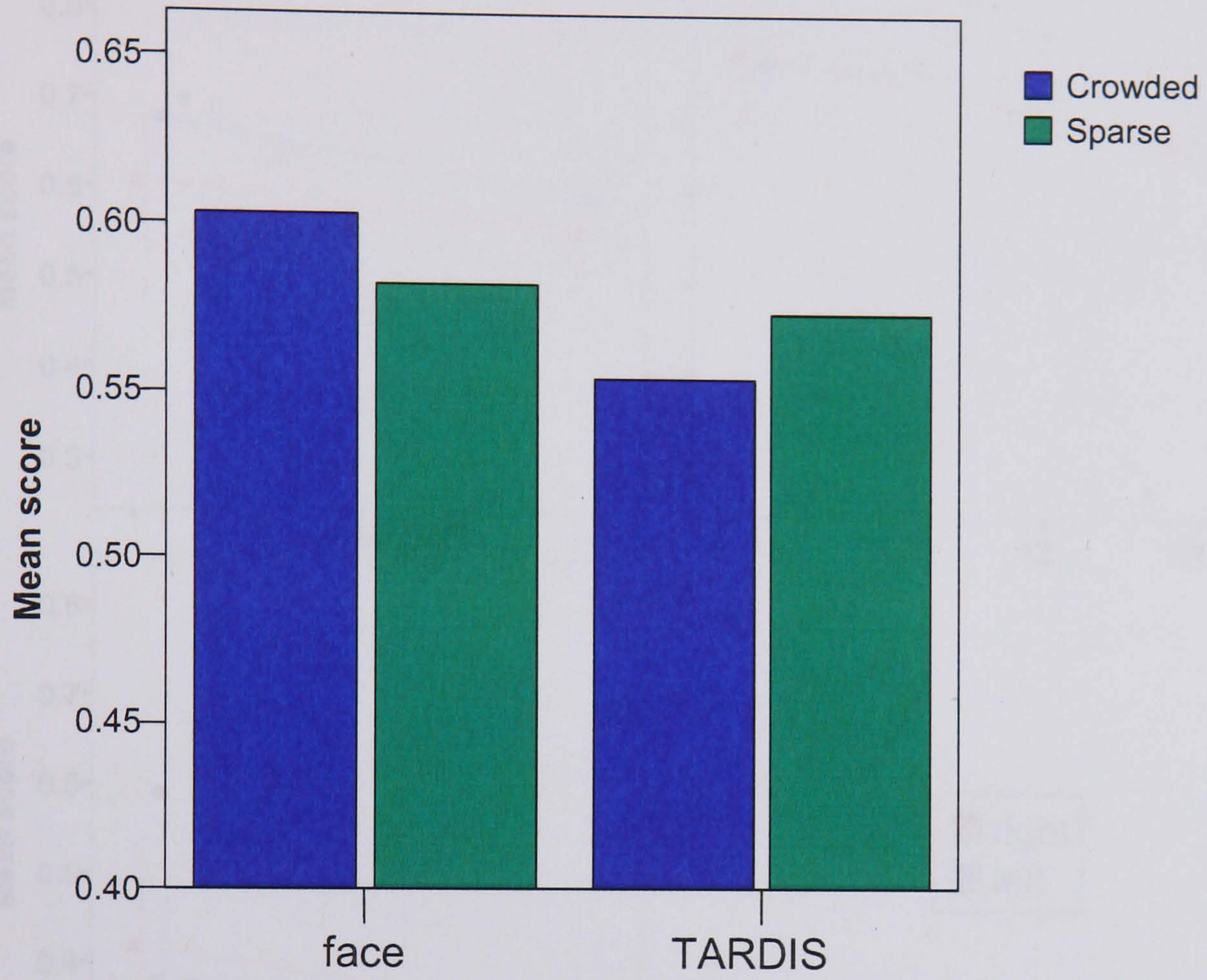


Figure 8.12: The mean scores for accuracy for the normal face stimulus and TARDIS stimulus in the 2 distribution conditions, sparse versus crowded.

Table 8.7 shows the differences in the mean scores and standard deviations for the two distribution conditions. The mean scores are very close for each of the conditions with only 5% difference between the maximum and minimum accuracies.

Table 8.7: The means and standard deviations for rows of 3 images presented in either a crowded, side-by-side, or a sparse, spread out condition.

Condition	Mean	SD
Face		
Sparse	0.58	0.14
Crowded	0.60	0.12
Tardis		
Sparse	0.57	0.13
Crowded	0.55	0.12

8.9.2.3 The effect of visual hemifield bias

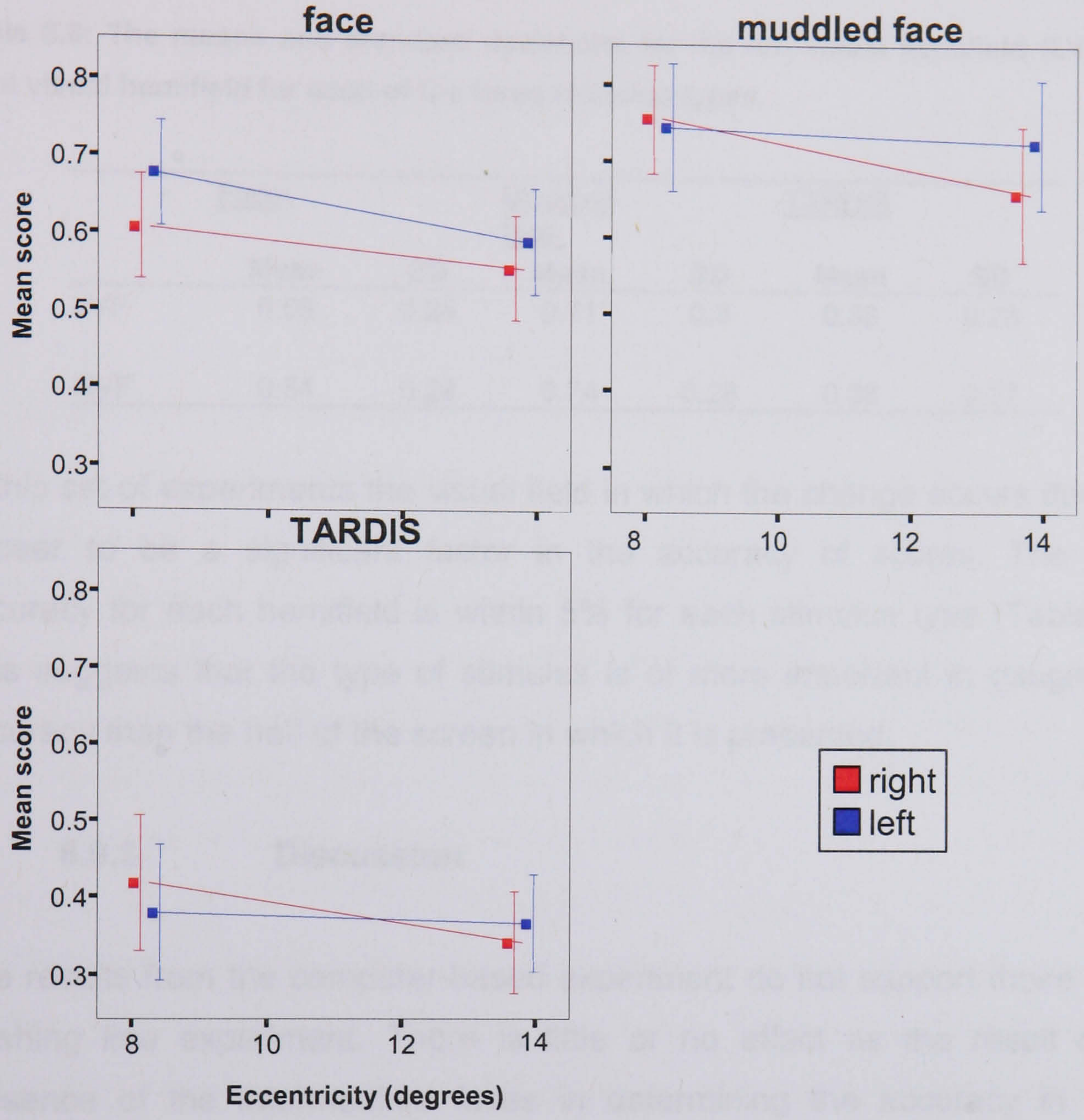


Figure 8.13: Left and right visual field bias in scores for faces, muddled faces, and TARDIS stimuli. Error bars represent the 95% confidence intervals.

A series of repeated measures within participants one-way ANOVAs were conducted on the effect of visual field on correct detection of change in either the normal face, muddled face and TARDIS conditions. There was no main effect for the VF for normal faces ($F_{1, 49} = 3.257$, $p = 0.077$, $\eta^2 = 0.062$) although as demonstrated in Figure 8.13 there is a visible trend towards a bias for spotting changes occurring in the LVF. For muddled faces there was no main effect for the visual field that the change occurs in ($F_{1, 49} = 0.967$, $p = 0.330$, $\eta^2 = 0.019$). Finally for the TARDIS stimuli there was again no significant main effect for the visual field in which the change occurred ($F_{1, 49} =$

0.038, $p = 0.846$, $\eta^2 = 0.001$). For faces there appears to be a general trend towards a bias to the left half of the screen however this is not clear for the other 2 conditions (Figure 8.13).

Table 8.8: The means and standard deviations for the left visual hemifield (LVF) and right visual hemifield for each of the three stimulus types.

	Face		Muddled face		TARDIS	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
LVF	0.59	0.24	0.71	0.3	0.38	0.28
RVF	0.64	0.24	0.74	0.28	0.38	0.27

In this set of experiments the visual field in which the change occurs does not appear to be a significant factor in the accuracy of scores. The mean accuracy for each hemifield is within 5% for each stimulus type (Table 8.8). This suggests that the type of stimulus is of more important in gauging the accuracy than the half of the screen in which it is presented.

8.9.3 Discussion

The results from the computer-based experiment do not support those of the washing line experiment. There is little or no effect as the result of the presence of the intermediate faces in determining the accuracy in which changes to the end images are identified. There appears to be a widening of the attentional window (Posner, 1980) allowing for the changes to be rapidly identified and very little effect as a result of the eccentricity of the stimuli. The eccentricities of the stimuli were therefore not sufficient to replicate the findings of the washing line experiment. There is an added problem that in the controlled environment of the computer experiment that the screen can be seen as a frame enclosing the window of attention within an artificially defined area.

The experiment did highlight the saliency of facial stimuli. Comparatively the change occurring to the TARDIS window involves an overall higher contrast change, yet was frequently not detected. The lack of detection of the TARDIS stimuli could be due to a either a lack of familiarity with the stimulus, as faces are rapidly identified, memorised and experienced more frequently than most other stimulus types. Secondly the TARDIS stimulus might have suffered due to it's regular repeated nature, this could have resulted in an illusory conjunction between images where although the change is very apparent there is a filling in of the gaps as much of the information presented is redundant. This second argument could suggest that the face as a stimulus captures attention as it is expected to be unpredictable in nature and always changing.

The muddled face condition exhibited the greatest accuracy in change detection. The muddled face contained all the elements of the normal face but not the configurational properties; previous research would have suggested that the normal face should have been the most salient target as it contained both the featural and configuration properties needed for rapid face recall (Tanaka & Sengco, 1997). The muddled face could have elicited attention as it could already be interpreted as being changed, this would mean that it might elicit greater attention than in the normal condition. Alternatively the lack of repetition and reflection within the faces could have made the changes more apparent. As with the TARDIS condition the normal face consists of elements that are approximately repeated and reflected, this could mean that to a degree the normal faces will also be subject to illusory conjunctions and information redundancy. The muddled face is the only condition in which this is not the case and therefore will not be subject to an automatic filling in or correction of the view due to information redundancy. This lack of symmetry could have an advantageous effect on its apparency, as there are no predetermined top-down expectations for how the row should like. Therefore faces are special but novel faces are perhaps even more special when it comes to attracting attention.

Finally there was not a significant effect for the side of presentation with neither the left hemifield nor the right hemifield having an advantage. However for the normal face condition there was a visual trend for a left hemifield bias, but this was not significant. This lack of an effect could have been the result of global processing of the groups as opposed to the local processing of the stimuli in the hemifield experiments. This could indicate that in the processing of the groups they were being perceived as crowds and not a series of individuals. This is an important distinction as this could be regarded as a defining difference between the perception of crowds and free forming social groups.

8.10 General discussion

The washing line experiment highlights the way faces are perceived within daily interactions. Internal validity and objectivity of responses are, however, difficult to control. The computer change detection experiment highlights that the change of test medium can have a significant effect on the results. The eccentricity of the stimuli for the computer-based experiments was comparable with those for the 5m-distance condition in the washing line experiment. The washing line experiments had eccentricities of 7.07° & 13.96° for the group size of 3 and 5 respectively compared with eccentricities of 8.26° & 13.82° in the computer-based experiment for the same conditions.

There is in general preference for group sizes of 3 individuals, this is in accord with those observed for free forming conversational group sizes (Dunbar et al. 1992). The positioning of the individuals within the retinal field of vision is significant and could prove to be a limiting factor. This suggests that in natural social encounters that faces within a group are detected serially, with the focus of attention aimed at the speaker or one particular group member. However, as demonstrated with the computer experiment if the groups are perceived at a global level then detection of changes within the social group would be difficult to detect. The results support the advantage for attending to 3 images as opposed to 5. This could represent a perceptual barrier in identifying more than 3 images as suggested by evidence from the cognitive limit and number perception literature (Pica et al., 2004; Gordon, 2004, Gelman & Gallistel, 2004; Cowan 2000; Broadbent 1975; Henderson 1972).

As identified by the shirts in the washing line experiment and the TARDIS' in the computer experiment, redundancy in the information content presented can have a detrimental effect on change detection. However, in natural free forming social groups the group members will not all be identical. This should make change detection more apparent as demonstrated by the muddled faces where there is an element of novelty. This redundancy effect can be noticed in the reports of clarity for the end shirts in that the reports are consistently high even though the shirt is not within the main focus of attention, i.e. the face of the central figure. However repeated elements appear to provide a useful tool for completing a visual scene as shown in the washing line experiments and a source for confusion when trying to detect subtle changes. As in the previous experiments the eyes did prove to be the most salient feature. The eyes appear to attract attention in a similar way to the changes in contrast of Gabor patches as demonstrated by Carrasco et al. (2004).

The results suggest that there are constraints on the perception of group size both as a result of the stimulus presented but also due to the retinal physiology. The blind spot was also identified as being a region within the retinal visual field that could reduce the accuracy of perception of group member. Filling in at a cortical stage of perception could compensate for this blind spot. The redundancy of repeated and reflected information allows this to occur. This process could be a top-down effect as there is an element of expectation as to what should be there, be it a missing TARDIS window or a patterned shirt.

To conclude the accurate perception of social groups appears to be reliant on several factors: group size, redundancy of information and physiological constraints. However when these constraints are added to those of auditory perception it is likely that the formation of small social groups is limited by the input devices, eyes and ears, and not by the processing capacity of the brain.

Chapter 9: Discussion

9.1 Aims of the thesis

This dissertation aimed to address:
(1) What constitutes a visual pattern?
(2) Whether people possess a proclivity towards one particular pattern type.
(3) When is patterning imposed or detected by the visual system?
These issues were examined in regard to both abstract patterns and patterns with higher ecological relevance, i.e. human faces and human social groupings.

Preferences towards pattern types were examined initially in a brief pilot study that asked members of the public to define the term pattern. These results were then used to construct a masking experiment to test whether these preferences were also present within the identification of images after brief periods of processing time. Both the pilot study and masking experiments were carried out using 10x10 square checkerboard patterns.

A second pilot study asked what people believed to be the defining qualities of a face. In this test participants rated abstract images along with more naturalistic images of faces and configurations. A second masking experiment was devised to investigate the saliency of individual features and the configural properties of the face in terms of the patterning.

As a consequence of the first two masking experiments, further investigation was conducted into which specific areas of the stimulus patterns appeared to be processed preferentially. For the checkerboard stimuli, this was done by presenting changes to different hemifields of the stimulus, i.e. top, bottom, left and right hemifields. For the face stimuli, changes were made to the left and right hemifields by either removing the left or right eye.

The final part of the investigation consisted of a preliminary study investigating how the results from the previous experiments could be interpreted within a more ecologically valid context, i.e. the perception of human social groups. Two experiments were conducted, one investigating group size perception based up life-sized stimuli, and the second investigating the group size in a computer based experiment. In the following sections the results and implications for each of the studies are summarised.

9.2 Summary of the pilot study results (Chapter 3)

In defining what is “pattern-like” there appears to be a bias towards looking for ways of reducing the information content within both abstract and facial patterns. In describing what constitutes a pattern participants tended to select definitions that confer an advantage in information processing via redundancy, such as increased symmetry and decreased numbers of variants. Participants tended to rate patterns with high figural goodness and a low number of possible variants as being most pattern-like. This was supported by a preference for patterns containing both repetitive and reflective symmetry.

The definition of what constitutes a face was very sensitive to the spatial arrangements of the internal components. Therefore there was a specific pattern that was perceived as being most face-like. This was a bisymmetrical triangular arrangement of elements in an inverted triangle shape. The features of the face were not perceived as being as important as the configuration. Therefore, the definition of a facial pattern tends to be at the configural level rather than the featural level.

The two pilot tests highlight possible top-down influences in pattern perception based upon the preconceptions of participants towards particular abstract and facial patterns. Patterns were more likely to be described as being pattern-like if they contained fewer possible variants, i.e. contained more redundant information. Top-down processes that utilise redundant information could provide preferential detection of different pattern-types: for example, the bisymmetrical configuration of the facial stimuli.

9.3 Summary of the symmetry masking experiment (Chapter 5)

Two different types of symmetry were further investigated in detail. These were repetition and reflection. Random, repeated, reflected and patterns that contained both repeated and reflected elements were masked at inter-stimulus intervals (ISI) of 0ms, 14ms, 42ms, 96ms and 208ms.

At an ISI of 0ms (i.e. the target image was presented for 14ms then immediately masked) there was greater accuracy in the detection of patterns that contained repeated elements over those that were either randomly generated or reflected. This could suggest a sub-cortical detection of the spatial properties of the stimulus based upon one small area, as the target image would have been interrupted prior to full encoding in area V1 and any extensive reentrant processing within the non-visual cortex. The poor recognition of the reflected stimuli at ISIs of less than 14ms could suggest that for these images to be identified there is more pattern matching or higher object-based recognition required.

At the higher ISIs (i.e. those greater than 96ms) there was a trend towards greater accuracy in the identification of the reflected images. The correct identification of reflected patterns was occurring within approximately 100ms, i.e. from the presentation of the target image to the beginning of the masking image. This suggests that the reflected patterns were being recognised more quickly than if perceived solely by bottom-up / feed forward grouping mechanisms (Kurylo, 1997) and that perhaps there was a top-down proclivity towards the detection of reflective symmetry. This top-down processing may have impacted on such early processing intervals providing a perceptual advantage for the reflected stimuli. At ISIs greater than 96ms repeated patterns were identified less readily than the reflective patterns and this was suggested as being the result of serial processing of the repeated elements.

Between ISIs of 42ms and 96ms there is a rapid increase in accuracy. This could suggest that around this time re-entrant processing of the images is occurring. This trend is common for all of the stimulus types and therefore suggests that this is a point when all stimuli are being processed in a similar fashion. This could reflect significant processing in area V1, between 40ms and 60ms post-stimulus presentation (Bullier, 2001). For the repeated elements this also coincided with a reduction and increase in the variance of reaction times at ISIs of 42ms. This may reflect a change in the processing of the repetitive stimuli from a more holistic spatial detection method towards an attentional serial processing strategy.

The number of repetitions at the earlier ISIs (0ms and 14ms) and therefore the size of the repeated elements had a significant effect on the early processing of the repeated stimuli. The greater the number of repeated elements and therefore the smaller the initial repeated element, the greater the accuracy in detection. In the reflective symmetry condition the number of possible variants (Attneave, 1954) did have an effect on the perception of reflection at higher ISIs (96ms and 208ms). However, this was not conclusive as the results mirrored those for differences between patterns containing reflection (i.e. possessing 2 or 4 variants) and that of random patterns (that contain 8 variants). Each of these pattern types corresponded in terms of number of variants so no firm conclusion could be generated.

The investigation of the importance of the axis of reflection produced conflicting results with reflection across the horizontal line of symmetry proving most salient at ISIs less than 42ms and greater than 96ms. This was not in accord with previous studies that state the vertical axis of reflection should be the most salient (Julesz, 1971; Bruce & Morgan, 1975; Dakin & Herbert, 1997; Oka et al. 2001). Due to the brief presentation times and insufficient time to shift the focus of attention there could be a left to right perceptual strategy. This could provide an advantage for patterns reflected across the horizontal axis because only one half of the pattern is being attended and therefore only reflection within this hemifield (i.e. LVF) would have the perceptual advantage. This was examined further in a subsequent masking experiment where participants had to judge the distances between pairs of dots. In this experiment there was the expected preference for detection of reflection across the vertical axis and for greater accuracy in detecting dots reflected proximate to the central axis.

In another masking experiment the factor of common direction was examined. In this experiment it was shown that at all ISIs there was an advantage for patterns containing common direction. This bias increased after ISIs of 42ms. In conclusion the checkerboard stimuli suggest an early advantage for repetition and common direction and later (>96ms) advantage for patterns containing reflection.

9.4 Summary of the face masking experiment (Chapter 6)

The importance of facial features, the eyes and the mouth, were examined in two different configurations, a normal and a distorted condition. Changes to the contrast of the eyes were also investigated. These images were masked at ISIs of 0ms, 14ms, 28ms, 56ms, and 154ms.

The results of the face masking experiment showed that there was a distinct bias towards the identification of either the loss or gain of the eyes when compared with that for the mouth. This bias towards the eyes was present within both the normal face configuration and the distorted face configuration. The features in the distorted condition were presented within a triangular configuration, however this configuration was not aligned along the orientation of the axis of reflection as inferred by the direction of the nose. The identification of changes was reduced in the distorted condition for both the eyes and mouth. This suggests that the configuration of the facial features in terms of the line of reflective symmetry may be a significant factor in the rapid perception of faces. The detection of the altered feature in the distorted condition appeared to follow a more gradual increase in detection with increasing ISI when compared with results for the normal face condition. This suggests a possible serial processing of the distorted face.

Nonetheless, the eyes proved to be particularly salient in both conditions. It was suggested that this could be due to the high contrast between the sclera and the iris or the limitations of the masking image to suppress processing. When the contrast between the iris and sclera was reduced to 70% of the eyes in the normal image there was a reduction in number of correct responses compared with the results of the normal faces. This suggests that contrast was an important factor in eye detection. However, the correct detection of changes to the eyes after contrast reduction remained greater than changes to the mouth across the range of ISIs, suggesting that the eyes remain the more salient feature.

The results suggest that the repeated nature of the eyes may provide redundant information and make the eyes a particularly salient feature in early vision. This is highlighted by the significantly greater success in detection of changes to the eyes in both the normal and distorted stimuli. This effect was further improved by the contrast of the eyes making them a salient feature. The results could suggest a top-bottom bias to scanning the face, or that the eyes capture attention. The configuration of the face in terms of the alignment of the features with the central axis of reflection had a significant effect on the correct identification of changes. This may suggest that the eyes capture attention and the positioning of the eyes relative to other features aids detection of changes.

In terms of patterning, the eyes provide a similar advantage as described in the repetition and common direction conditions within the checkerboard masking experiments. The configuration of the face, i.e. the reflective symmetry, aids the location of the features across a central vertical axis of reflection. Therefore the eyes may enable rapid judgments regarding the features to be made by possessing reflective symmetry proximate to the axis of reflection, repetition, common direction and high contrast.

9.5 Summary of the hemifield bias masking experiments (Chapter 7)

Two different types of stimuli were investigated in these experiments, namely checkerboard patterns and faces. The checkerboard patterns were presented in the same conditions as in the symmetry masking experiment, masked at

ISIs of 0ms, 14ms, 42ms, 96ms and 208ms. The face stimuli were masked at ISIs of 0ms, 14ms, 28ms, 56ms, and 154ms and presented in two experiments one using the stimuli from the face masking experiment and the second using photographic stimuli.

The results of the checkerboard hemifield experiment showed that there was a bias towards detection of changes in the left side and top half of the target stimulus. Repetition had an advantage over reflection in the right hemifield suggesting that the redundant information contained within repeated stimuli aids identification of stimuli when the whole image is not fully attended. However in the top/bottom variations there was no bias towards one symmetry type in the identification of changes. These results could suggest that the extrapolation of patterns may be preferentially carried out across the horizontal plane, i.e. from the LVF to the RVF.

The results of the first face hemifield experiment showed that there was a bias towards detecting changes to the eyes in the left hemifield. However, faces provide a special case in that emotional expression appears to be stronger in the left side of an individual's face, which is presented to an observer in the right hemifield. Therefore, either the facial expression has evolved to compensate for this dichotomy or the LVF bias has developed to focus attention towards the weaker signal. A second experiment was conducted factoring in gaze detection, whereby the participant had to identify which direction a face was looking. Again participants showed a bias towards correctly identifying changes to the left hemifield. However there was also a bias towards eyes looking to the right in the right half of the face. This was in accord with the previous finding that the saliency of the eyes is partly the result of contrast as the eyes looking right will provide white sclera on the left-side of the eye (Ando 2004, 2002). This may suggest that the eyes might be directing the orientation of visual search, i.e. if the eyes look to the left there is a bias on the participants to remain focused on the left side of the face. However if the eyes are looking to the right then there is a tendency to look across the face.

The second face experiment also examined the effect of gaze direction (i.e. common fate) with regard to hemifield biases. In the detection of gaze direction, accuracy was increased if both eyes were looking in the same direction, i.e. they both share common fate. This would be particularly important when having to look across the face to follow eye gaze to the right, therefore the eyes not only provide redundant information but can also provide supplementary information to facilitate gaze detection.

9.6 Summary of the effect of patterning and early visual processes on the perception of group size (Chapter 8)

9.6.1 The washing line experiment

The patterns present within the face might constrain the perception of other faces within a social context. This was tested in a preliminary experiment that examined participants' subjective ratings of life size images of people hung across a washing line in groups of 3 or 5 individuals at distances of 1, 3 and 5m from the participant.

The results suggest that the faces on the periphery of a social group are seen more clearly if there are only 3 individuals present within the group. This is in accord with those observed for free forming conversational group sizes (Dunbar et al. 1992). The eccentricity of the images to the participant was also controlled and as expected there was greater clarity in the end faces at lower eccentricities. This could represent a perceptual barrier in identifying more than 3 images as suggested by evidence from the cognitive limit and number perception literature (Pica et al., 2004; Gordon, 2004, Gelman & Gallistel, 2004; Cowan 2000; Broadbent 1975; Henderson 1972).

However, the constraints on the clarity of perception of the individual could have been in part due to the disruptive effects of the blind spot at eccentricities between 13° and 22°. Although the visual system fills in information within the blind spot with information from the temporal field of the other eye, this area will not necessarily be as clearly perceived. Repeated elements can easily be filled in across the blind spot, however complex configural information such as that of the faces might not be as easily filled in. When the images were distributed at one body width apart (65cm) the end figures were more clearly seen than if an intermediate face was presented in between the fixation figure and the end figure. This suggests that there might be a constraining effect on the attentional window as a result of the faces capturing attention.

The eyes were rated more often than the mouth as being clearly seen on the end figures. This could be due to the repeated nature of the eyes within the point of focus making it easier to extrapolate across all the images. However, the shirt of the figure that comprised of a complex check pattern was rated as being clearly visible on the end figures at all times. This could be because the participants were aware of the distinct spatial characteristics and able to extrapolate this across all the images. The main conclusion drawn from this experiment was that faces constrain the focus of attention towards primarily one individual at a time. Therefore in a social situation the repeated elements, i.e. the individual people, may be scanned in a serial manner both due to the field of vision occupied by social groups and the capturing of attention by each individual face.

9.6.2 The computer group size experiment

Three stimulus types were examined in the computer-based experiment. These stimuli were normal faces, faces with jumbled features and a TARDIS (police phone box). The stimuli were presented in a row and presented under the same conditions as in the washing line experiment at a maximum eccentricity of 13.82°. The stimuli were presented for 28ms and included a brief change to either the eyes or windows within the image. The participant had to identify if a change had occurred within the array.

Unlike the washing line experiment the presence of intermediate faces did not constrain the focus of attention in this experiment. There appears to be a widening of the attentional window in this case (Posner, 1980). This allows for the changes to be rapidly identified and very little effect as a result of the eccentricity of the stimuli. This could have been due to a framing effect as a result of the computer screen. The brightness of the computer screen in relation to the surrounding room may have widened the focus of attention improving multiple object tracking.

The facial stimuli, both distorted and normal, proved highly salient compared to the non-face stimuli. The salience of face-type stimuli reflects the findings of Tanaka and Sengco (1997). This bias towards faces could have been due to the familiarity of the facial stimuli or due to the highly repeated TARDIS stimuli inhibiting the perception of the non-face stimuli. The regular repeated nature of the TARDIS was similar to that of the shirts, and may have resulted in the filling in of any missing areas. This could have resulted in an illusory conjunction (Treisman & Schmidt, 1982) between the individual elements, inhibiting the detection of missing elements.

The muddled face condition resulted in the greatest accuracy in change detection. This was not expected, however, this does suggest that the repetition of stimuli that contain repeated and reflective elements can inhibit the perception of other similar stimuli in a grouped (repeated/reflected) situation. As the muddle face contained no bilateral symmetry and the features were not presented in the orientations that enable the formation of a configural triangle, as in the face masking experiment, these stimuli might have been processed serially. As there was no masking of the stimuli there was plenty of time for participants to complete the visual processing of each stimulus. Therefore in the muddled face condition, detection might have been spotted within the periphery of the visual field, as there were no patterned rules to suggest any particular continuation of the sequence. So in the normal face and the TARDIS condition the symmetrical properties, both repetition and reflection, might mean that any changes occurring to these images could have been filled in during later visual processing. Thus, in this experiment the patterned nature of a stimulus may have inhibited perception as a result of information redundancy.

There was no hemispheric bias in the perception of the grouped stimuli. Participants did not exhibit a bias to any particular visual field. The lack of a masking stimulus may have allowed for the completion of visual processing or the grouped nature of the stimuli might have allowed for the perception of the images holistically rather than individual elements.

9.7 General discussion of the results

The ability to predict events and generate conclusions based upon "patterns" is a characteristic that has enabled humans to control and manipulate their environment. Such capacities illustrate the human predisposition for identifying patterns. However, there has been little research into which characteristics of a pattern are of particular salience and how the visual system initially detects such stimuli. The term "pattern" is often taken for granted in perceptual literature. The public perceptions of what can be considered as being a visual pattern suggest insights into what top-down processing biases might affect the preferential perception of particular pattern types during brief presentations. These factors included symmetry types and aesthetic preferences. The link between aesthetic preference and reflective symmetry has been an area of extensive study in both humans (Perrett et al., 1999; Mealey, Bridgstock & Townsend, 1999; Jones et al., 2004; Jones et al., 2003; Little et al., 2001; Jones et al., 2001; Opitz & Utkus, 2001) and non-human species (Möller, 1990, 1992, 1993, 1995; Harvey & Walsh, 1993; Morris & Casey, 1998). The pilot study results confirm this preference.

The perception of patterns in both abstract and social stimuli can be regarded as being strongly affected by the perceptual hardware. Hemifield biases within the masking experiments provide an advantage for stimuli that are more completely represented within the left visual field. Therefore patterns that exploit this, such as repeated patterns that contain a large amount of redundant information and patterns reflected across the horizontal axis, will be detected first. However, this bias in visual hemifield perception only benefits patterns that have information that can be extrapolated across to the right hemifield. There was also an effect for preferential perception of the top half of

a stimulus compared to the bottom half, providing a further advantage for patterns with a greater number of repeats at early ISIs (<14ms).
However, at ISIs greater than 42 ms there appears to be the influence of top down processing. At this point there is an increase in the saliency of all stimuli, faces, abstract and distorted faces. This would reflect the evidence from neurological studies that suggests that face recognition can occur as early as 50ms or 80ms (Seeck et al., 1997; Oram & Perrett, 1992).

Repeated patterns appear to be more detectable than reflected patterns at ISIs less than 14ms. The redundant information present within repeated patterns might be advantageous when the information that can be gleaned from a stimulus is minimal. The low acuity spatial properties of a stimulus, i.e. contrast differences, can be detected via the superior collicular pathways and do not require extensive cortical processing but orientate attention towards particular areas, predominantly peripheral, of the visual field (Schiller et al., 1979). The repeated patterns could take advantage of this in that the small amount of information perceived could be extrapolated across the spatial map of the stimuli to areas that are not being perceived directly via the main cortical pathways.

The reflectively symmetrical stimuli elicit greater saliency at ISIs greater than 96ms at a point where grouping of the stimuli would be occurring. This preference for identifying reflective symmetry at a stage when perceptual grouping is occurring (Kurylo, 1997; Tyler, 1999) suggests that there may also be aesthetic biases already at this stage in that the images are processed as wholes, i.e. the visual system registers the stimulus in terms of a coherent percept. When compared with repeated stimuli that do not achieve this level of saliency within the masking experiments, there appears to be a consistently lower accuracy in change detection at 96ms. This could be due to serial processing of the repeated stimuli at this interval. This serial processing would be in accord with representational theories (van der Helm & Leeuwenberg, 1996).

The human visual system could exhibit a top-down processing bias towards detecting information that is reflected across a vertical axis. This would enable rapid identification of food, predators and tools all of which exhibit bisymmetrical properties and are essential to an animal's survival. These conditions would be preferentially detected at the later ISIs (>42ms). Some stimuli appear to be generally more salient than others. The former include the eyes that combine the advantages of repetition and reflection with a large difference in contrast between the sclera and iris. This suggests that the biases exhibited in pattern detection make the eyes a particularly salient facial feature. Evolutionary studies suggest that there are preferences for looking at faces that exhibit bilateral symmetry (Jones et al., 2004; Jones et al., 2003; Little et al., 2001; Jones et al., 2001; Opitz & Utkus, 2001). This would be supported by the preference for non-distorted faces where the line of reflective symmetry inferred by the nasal ridge is within the central axis of the configural triangle created by the eyes and the mouth (Barton et al., 2002).

The eyes are used as a signalling device to communicate intentions and emotions (Tanaka et al., 2003;Trepagnier et al., 2002; Ruffman et al., 2001; Yirmiya et al., 1999; Leekam et al., 1998; Baron Cohen, 1999; Baron-Cohen et al, 1997). Therefore the repeated nature of the stimuli can both amplify the signal via the high-contrast repeated nature of the eyes (Ando, 2002; Ricciardelli et al., 2000) and provide redundant information that will allow for deficits in attention. By combining the benefits of both repetition and reflection the eyes can communicate a rapid signal that is detectable by the observer. Whether the visual system has adapted to take advantage of this or the evolution of the high-contrast eye is the product of biases already present within the visual system cannot be determined. However the high contrast sclera is a characteristic within primates that is exclusive to humans.

The configural arrangement of the features within the face might result in a directional bias in perception. As illustrated in Figure 6.1, the inverted triangular arrangement of the eyes and mouth could provide a convenient perceptual cue directing attention away from the eyes towards the mouth. As suggested in experiments where arrows were used to redirect attention

(Tipples, 2002), automatic orientation can occur as the result of any directional cue. Therefore, not only does the eye gaze provide information about an individuals state of mind, but the bisymmetrical configuration of facial elements allow for the eyes to shift attention downwards towards the mouth which is also an essential feature in communicating information visually (as well as orally).

In more ecologically valid surroundings patterns are not encountered as individual images but as part of other patterns and are therefore fractal in their nature. The human visual system has to use this information as economically as possible and distinguish between the edge boundaries and make judgments regarding which pattern belongs to which perceptual element within the visual field. At one level the human face can be considered as a fractal pattern with the individual elements exhibiting approximate bilateral symmetry as well being arranged in reflective manner across a vertical line of symmetry. However the human face is frequently encountered within groups, and these groups can be perceived as highly repeated patterns. The most commonly experienced form of grouping is that of the free forming conversational group. This creates a processing problem in that the face that is being fixated primarily will capture attention and reduce perception of peripheral group members. Although it is possible for group members to scan from individual to individual, this would result in a loss of valuable information being communicated by an individual who might be speaking. However by limiting the group size, the saliency of the eyes will allow for rapid shifts of attention towards new contributors within the conversational group.

The group scenario provides an advantage for repetition as demonstrated by the identification of the eyes and the patterned shirt in the peripheral figures of the washing line experiment. This shows that when processing time is not limited that repetition can prove to be a particularly important amplifier of a signal (Porthos & Ward, 2000). The mouth is repeated half as often as the eyes and therefore not as salient, also the presence of multiple faces reduces the effect of the facial configuration in that attention is not being directed towards the mouth from the eyes but across to other faces. The muddled faces of the computer based grouping experiment show that a lack of configuration actually increases the saliency of peripheral images.

To conclude there is bias towards patterns that contain both repeated and reflective symmetry by members of the public defining what constitutes a pattern. Repetition and reflection are differentially processed within the early stages of visual processing. Each of these symmetry types confers a perceptual benefit at different stages of visual processing with a bias towards repetition at early phases (pre-rentrant processing, <60ms) and reflection at later phases (post V1 with reentrant processing, >60ms). Patterning can therefore be concluded as being imposed at an early stage of perception. This reflects evidence from neurological studies on perceptual grouping, symmetry detection and face recognition (Seeck et al., 1997; Oram & Perrett, 1992; Kurylo, 1997). However, limitations due to the capacity of the visual system might explain these differential biases towards either repetition or reflection at different stages of perception. These limitations may include attentional limits, right hemisphere dominance in early perception, and the presence of the blind spot for larger stimuli (e.g. groups of people).

The human face can be considered as a pattern and results from the masking experiments support the idea that the eyes are the dominant feature and exhibit repetition and reflective properties. Face perception is also constrained by the attentional biases and hemifield biases. However, repetition of features in the face can act as both an amplifier as well as providing redundant information. The preference for reflective symmetry in later stages of visual processing focuses attention onto one aspect of an image and is suggested as being a property used in distinguishing figure from ground (Baylis & Driver, 1995). In face perception this is essential in identifying the face as a configural whole.

9.8 Limitations

The available resources limited the conclusions that could be made from the experiments. EEG recordings during the masking studies would have helped in drawing conclusions based upon the results obtained, specifically the early role of repetition. The hemifield experiments could be the result of cultural biases in perceiving images from the left to the right. A cross cultural study and the use of fMRI technology would have allowed for conclusions about the role of the right hemisphere in early vision to be drawn. However, given the time constraints on the research process the studies provided within the thesis provide a basis for further investigation using additional techniques.

Ideally a wider range of abstract and facial stimuli would have been used in the masking experiments. However, in order to counter balance the stimuli to provide a 50/50 chance of guessing a correct answer and to present all stimuli at all ISIs, the number of target stimuli had to be limited. One of the benefits of the employed methodology was the use of a large range of people unfamiliar with psychophysical methodologies and perceptual experiments; this provided a sample that would reflect how patterns are perceived in daily life and not solely in the laboratory. However, in order to increase the sample size the number of trials had to be reduced so that all experiments could be completed within one hour.

With the facial stimuli, a wider variety of facial types (e.g. both male and female) might have benefited the experiment, as faces not only provide pattern information but also emotional, social and sexual information. There could be gender biases in the perception of different patterns within the face based upon gender differences in mate choice preference. Given the time constraints and moderate sample size the number of faces used had to be limited. The use of photo fit faces enabled the creation of original faces and eliminated the chance of a participant recognising a particular face prior to the experiment. However, face recognition could have provided a confounding variable for the washing line experiment as the images were of the experimenter and this could have been intimidating within a lab setting.

The washing line experiment was limited in the conclusions that could be drawn due to the subjective nature of the experiment. The variation of stimulus types, perhaps reflecting the computer based experiments, may have aided in the confidence with which patterning and the role of facial stimuli can be concluded as limiting the field of view. Ideally a life size stimulus that can be manipulated by the participant in terms of contrast and repetitions would have allowed for more quantitative ratings in the saliency of stimuli. However, where limitations exist there is an opening for further investigation.

9.9 Implications for further study

Despite the limitations the conclusions from these experiments provide a basis for further research into both face perception and the role of patterning in early vision. The findings of this thesis suggest that the conclusions from research into both pattern perception and face perception are limited by the ability to present the information within a natural context and to adequately control extraneous variables. Further experiments exploring the links between natural stimuli and abstract stimuli would benefit not only interpretations of the results contained within this thesis but also the results of psychophysical experiments carried out under internally valid conditions.

One of the benefits of this thesis is that it highlights the importance of trying to situate experiments that are usually computer based within a wider ecologically valid context. Unfortunately visual stimuli are rarely encountered in isolation and perhaps experiments that encourage the situating of visual stimuli, for example as in the washing line experiment, will allow for new conclusions to be drawn from previous studies. A useful area of further study would be to examine the effect of framing by computer screens on the results of vision based experiments.

The eyes can be examined further in terms of being the principal component in judging facial symmetry, and perhaps a greater focus should be placed on the role of the nose as a provider of bisymmetrical information. Patterns can be identified within virtually any stimulus and the human visual system appears to impose patterning on the perception of stimuli. Therefore the possibilities for further study are extensive.

9.10 Summary of conclusions

1) What constitutes a visual pattern: A visual pattern was defined as an image that contains redundant information. This was illustrated by a bias when defining patterns by members of the public towards those that contain both repeated and reflective symmetry, or a low number of possible variants and therefore possess a reduced information content, i.e. more redundancy (Chapters 3 & 5). Patterning continues throughout a visual scene from the local level to the global level, as such both the human face and human social groups can be perceived as patterns.

2) Is there a bias towards one particular pattern type: There appears to be a bias during early visual processing for patterns that contain symmetry (i.e. repetition or reflection), or share common fate (Chapter 5). There appears to be hemifield biases in the early detection of patterns, with a top-hemifield and LVF bias. Patterns that take advantage of these properties such as the eyes within the face may have a perceptual advantage (Chapters 5 & 7).

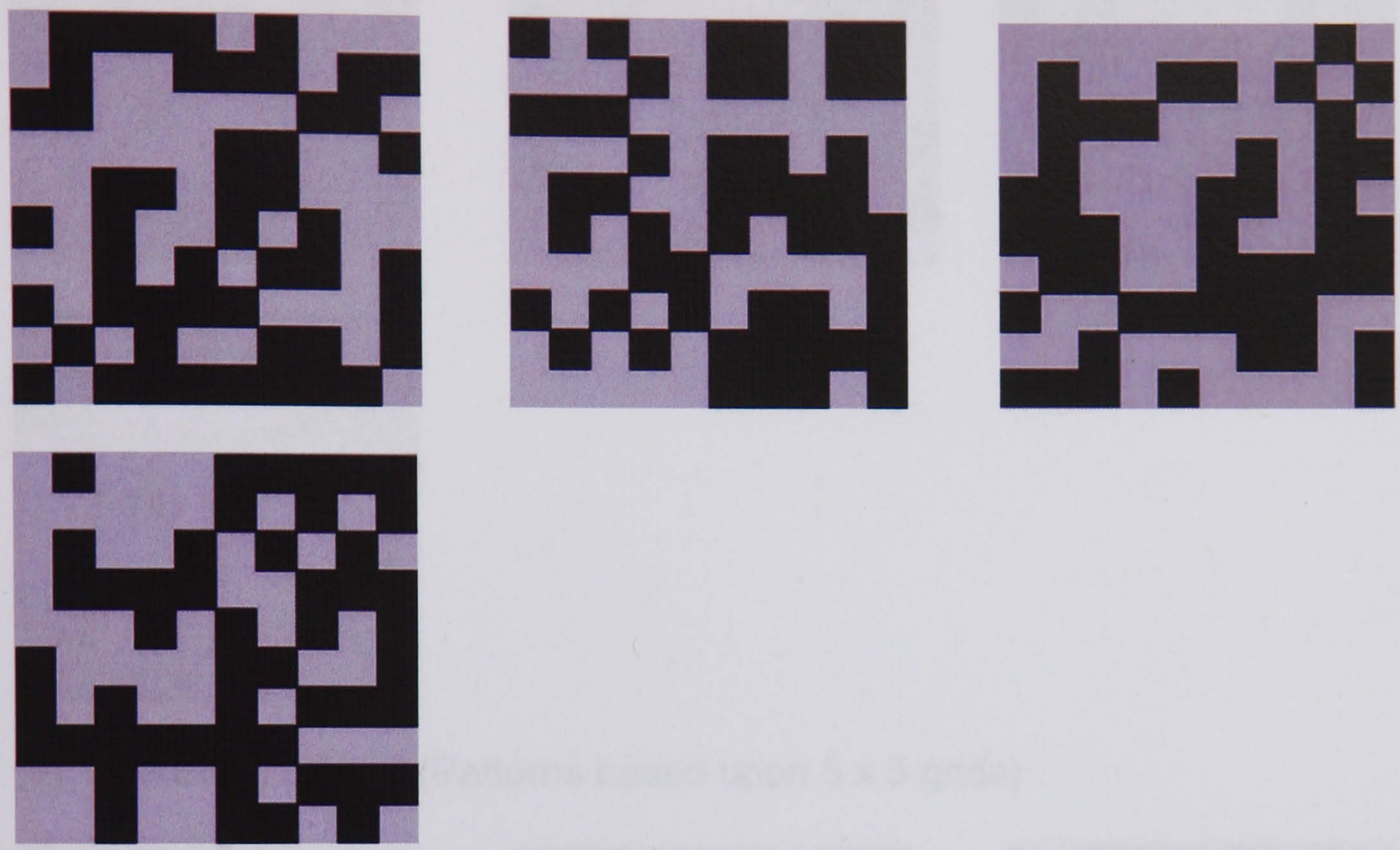
3) When is patterning detected within the visual system: Patterning appears to be imposed at all stages of visual processing (Chapter 5 & 6). At early stages of visual processing, repetition (and in the face the eyes) appears to have an early perceptual advantage over reflection. This could be due to early parallel processing and the use of the peripheral visual system. However at later stages of processing repetition appears to be processed serially and loses the perceptual advantage over reflection (ISIs >42ms). However, reflection has a perceptual advantage post V1 (ISIs >96ms). At post-recognition stages of pattern processing there is a perceptual advantage for repetition within peripheral vision, i.e. the eyes vs. mouth in the group size (washing line) experiment (Chapter 8).

Appendix A

Examples of Test Stimuli

A) EXAMPLES OF THE BASIC STIMULI FOR ABSTRACT MASKING CONDITIONS

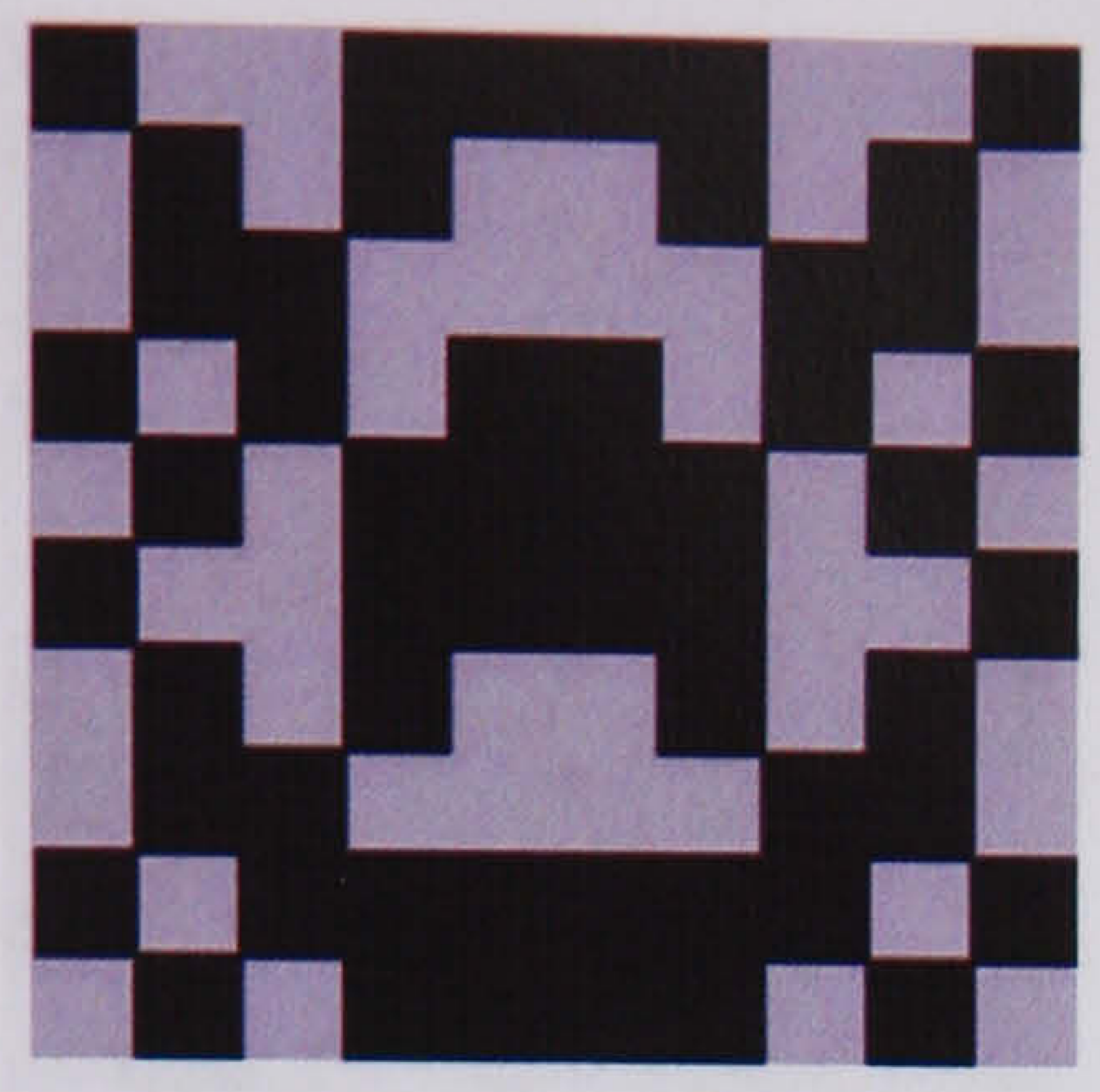
i) RANDOM 10 x 10 grids

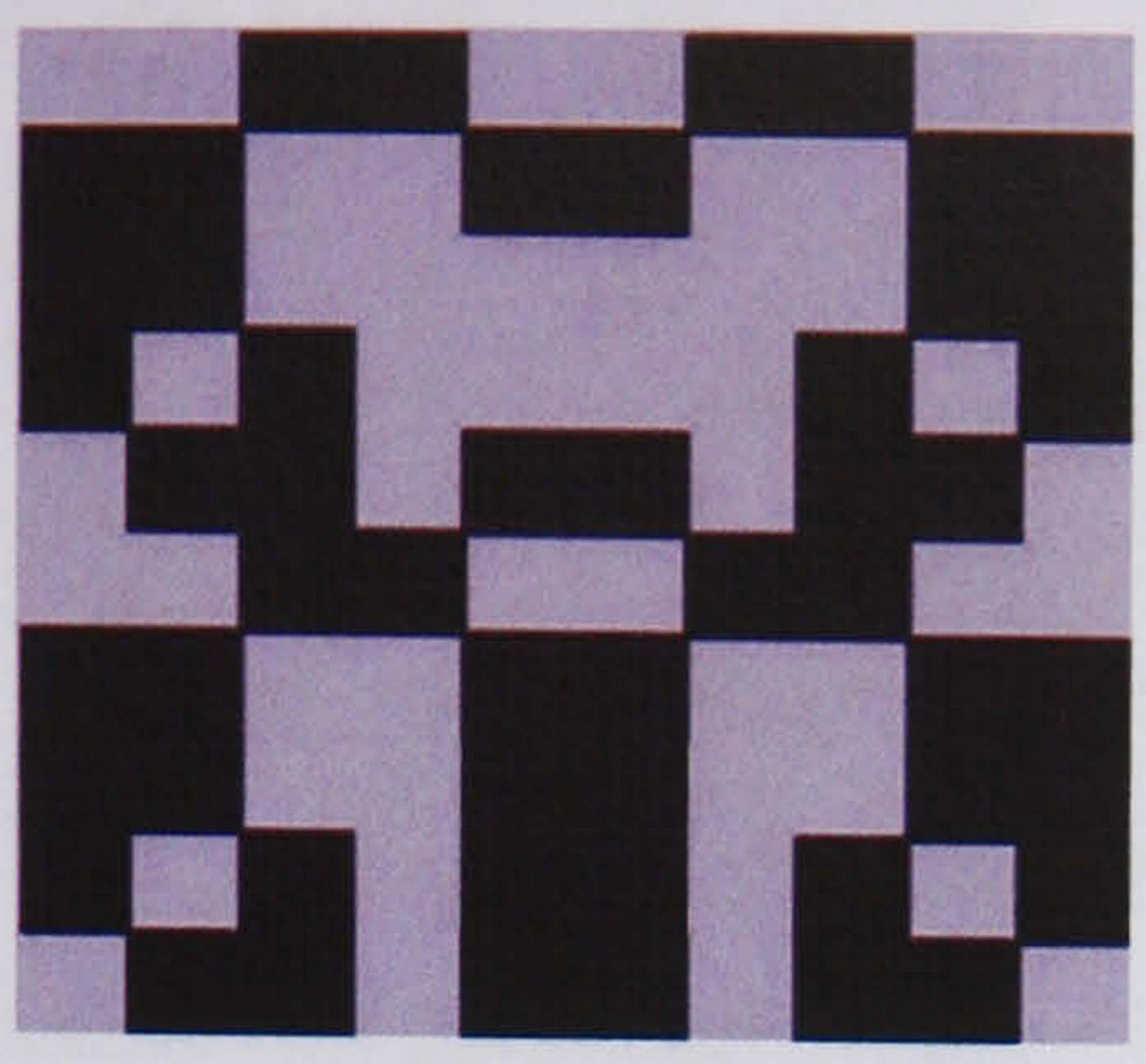


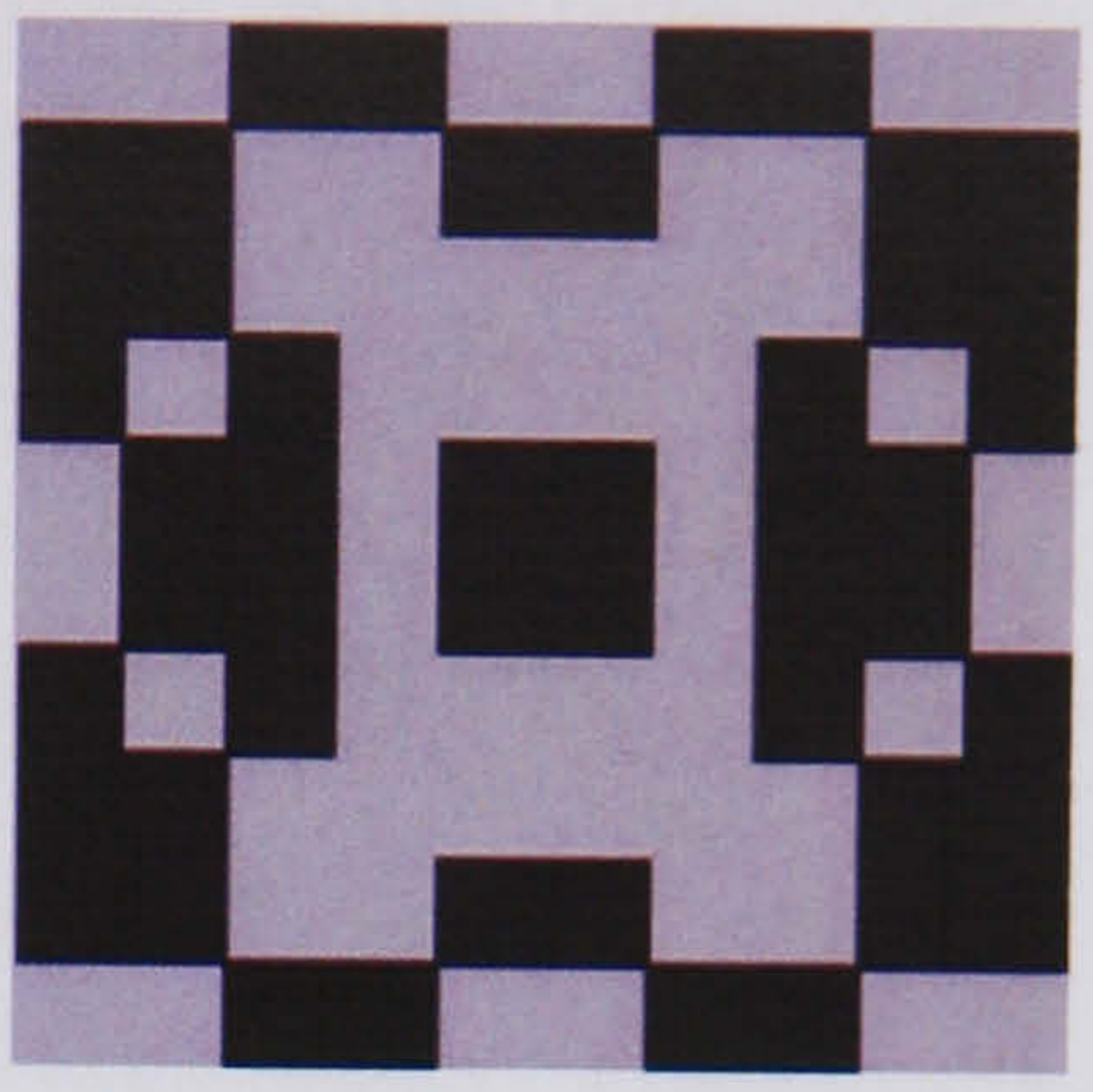
ii) RANDOM 5 x 5 grids

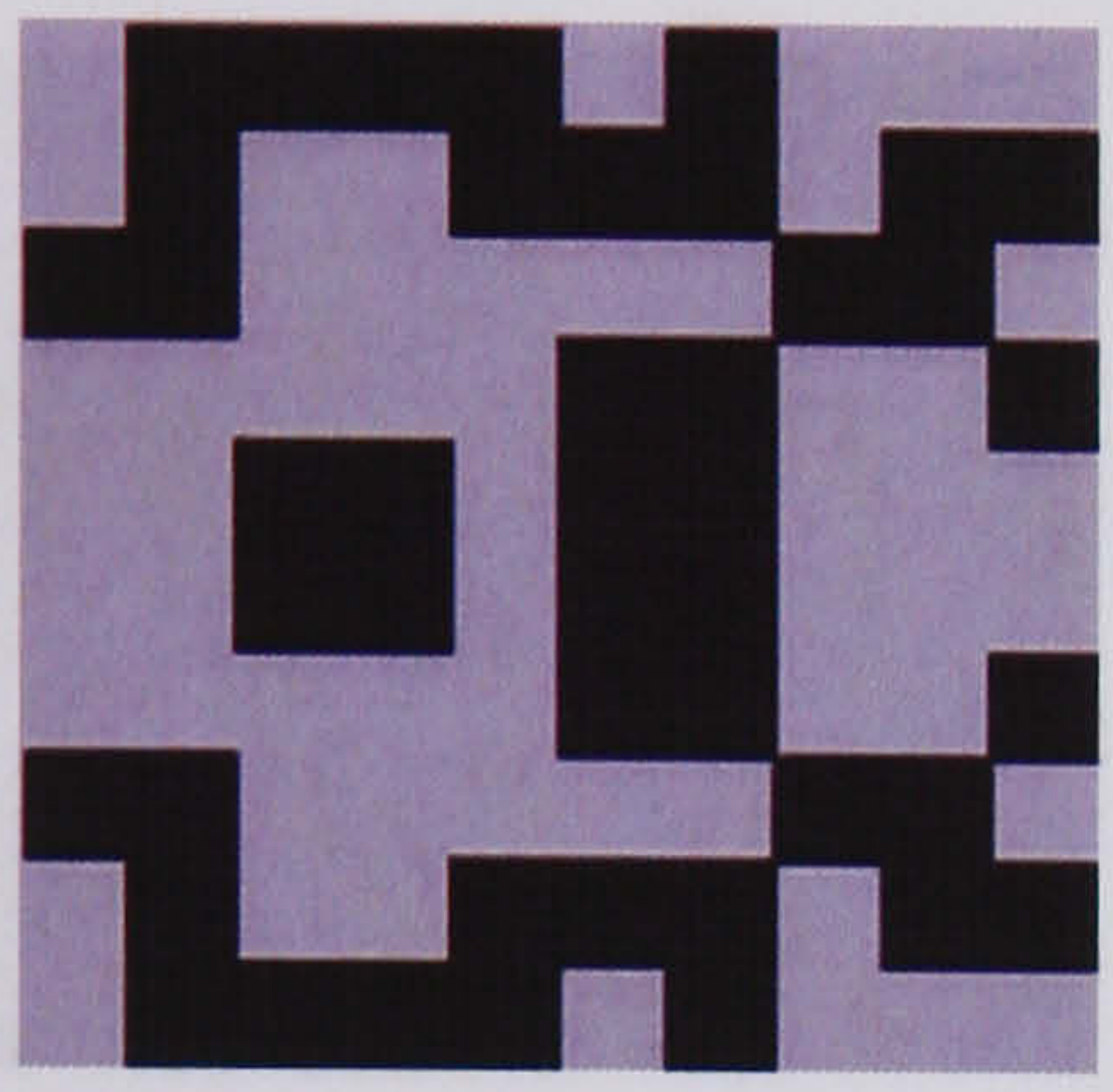
These test stimuli were also presented in negative to counter balance for differences in luminance and in all 4 possible rotations.

iii) **REFLECTION** (Patterns based upon 10 x 10 grids)

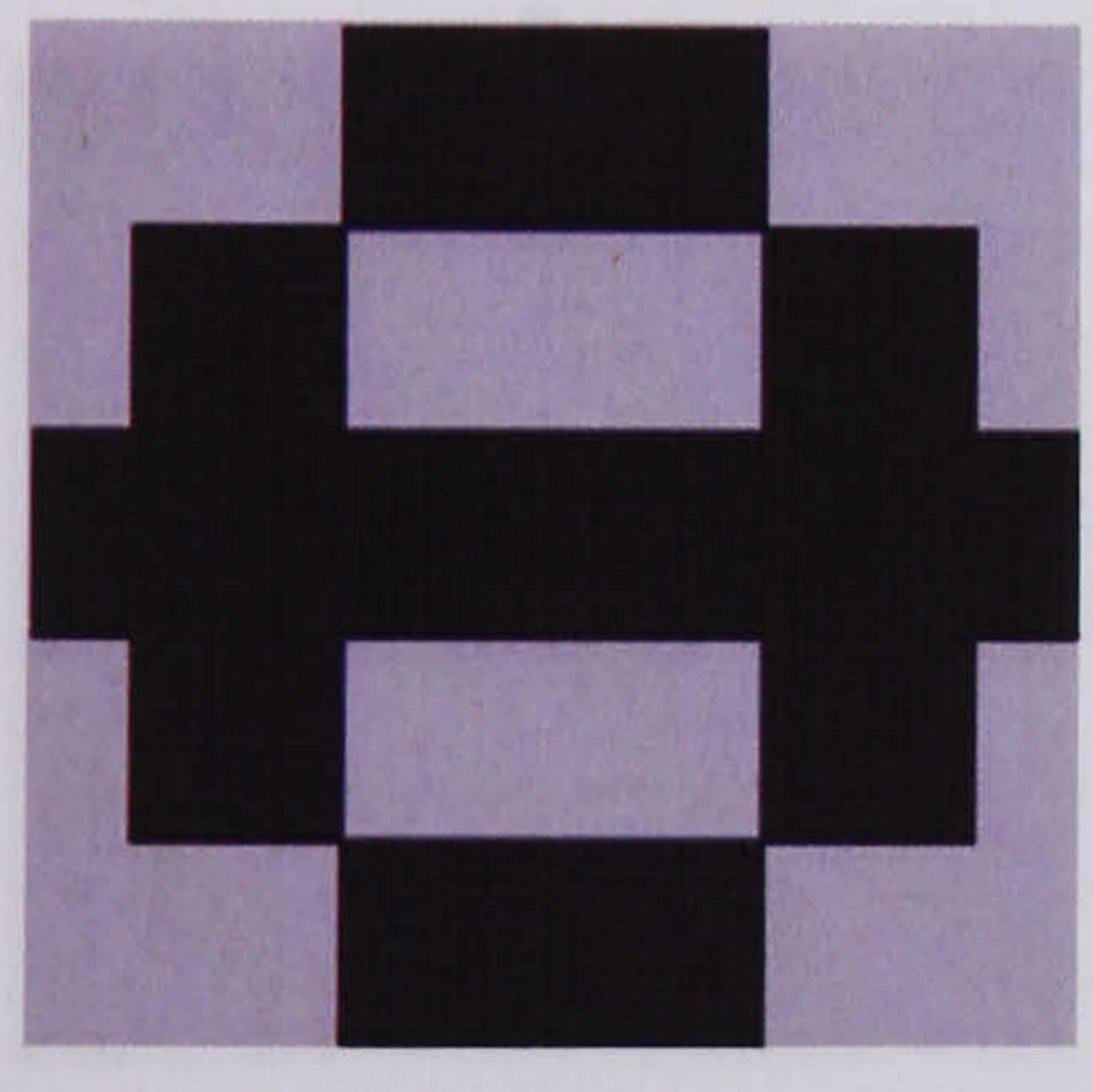


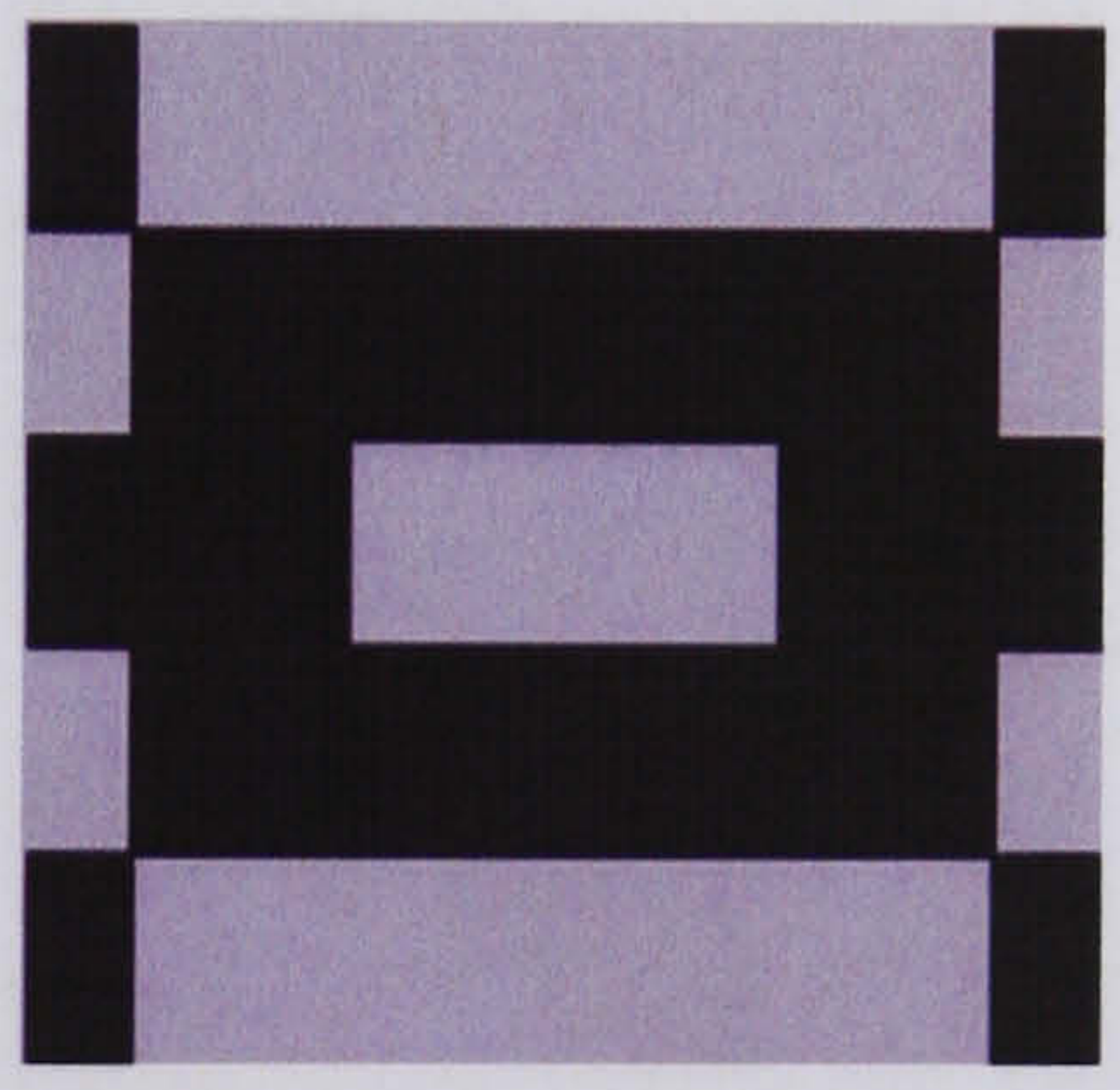


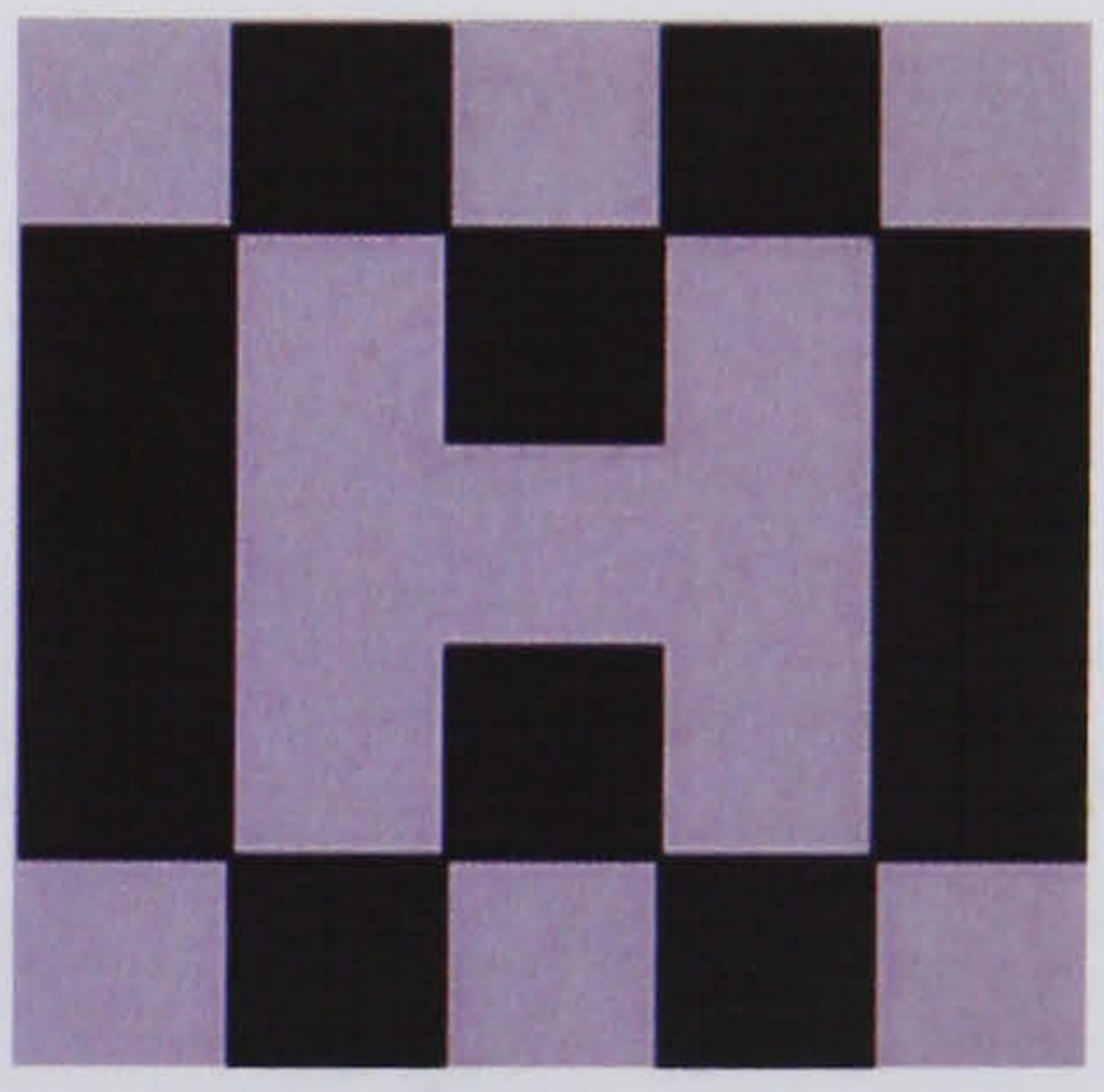


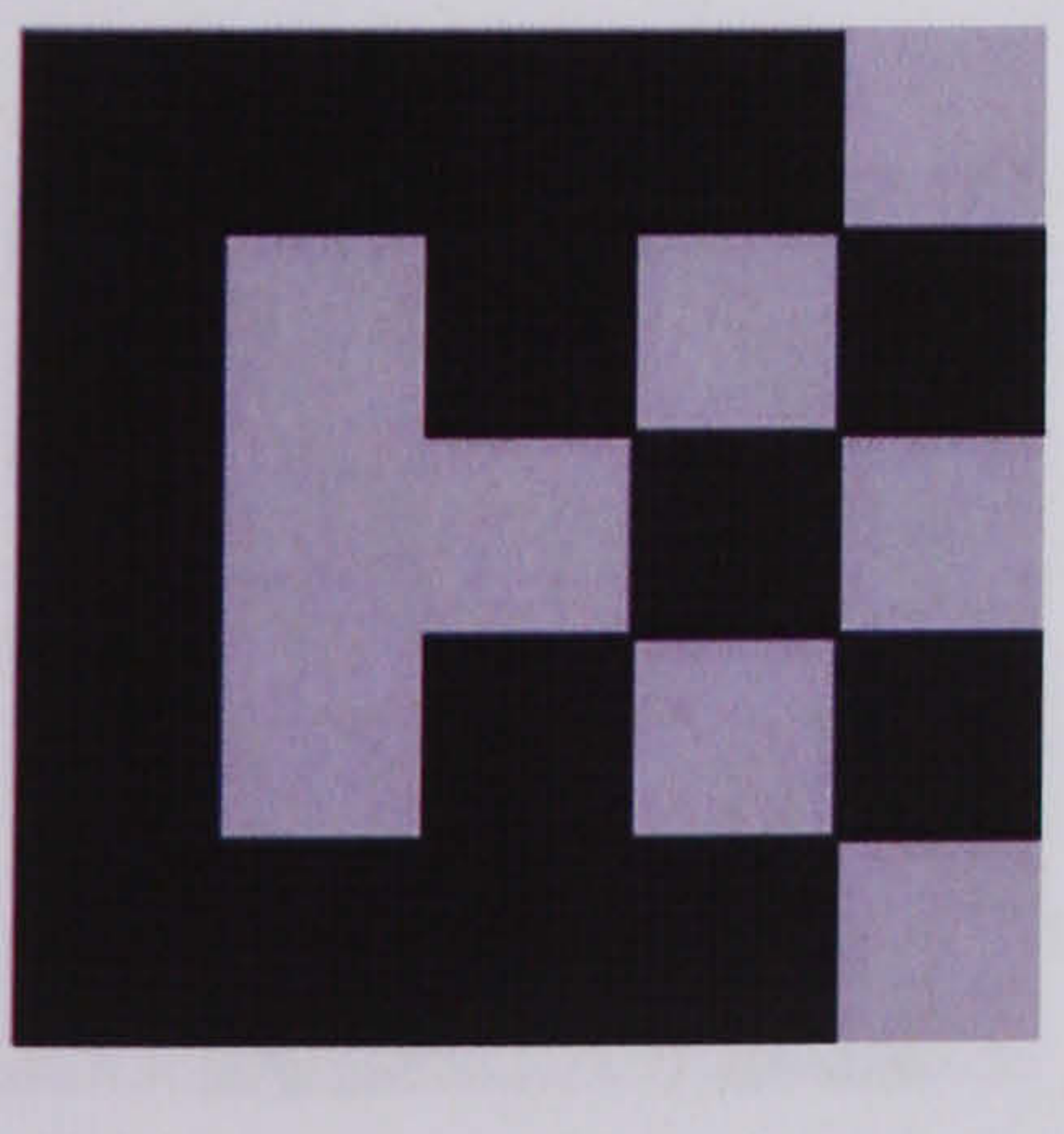


iv) **REFLECTION** (Patterns based upon 5 x 5 grids)



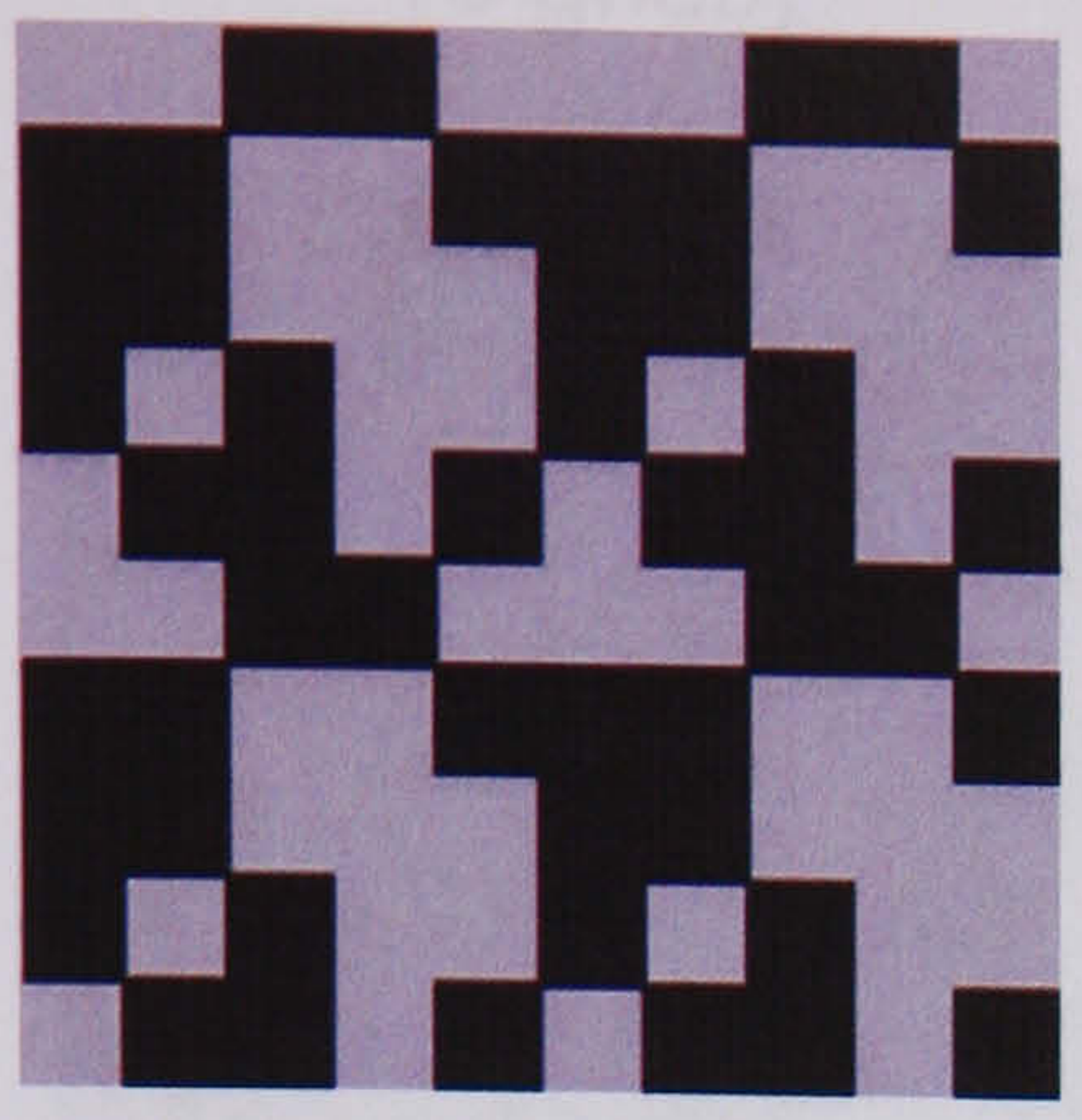


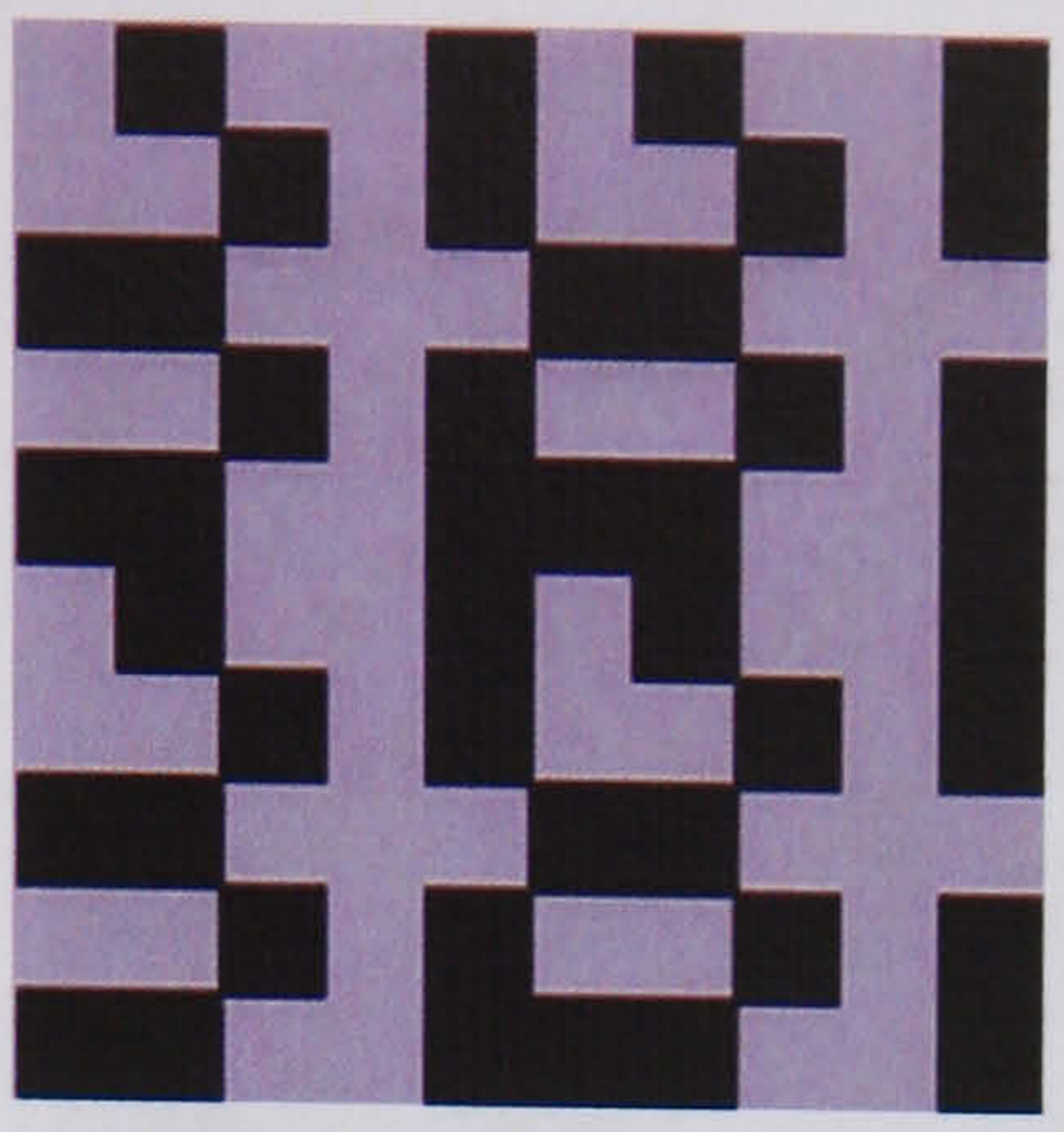


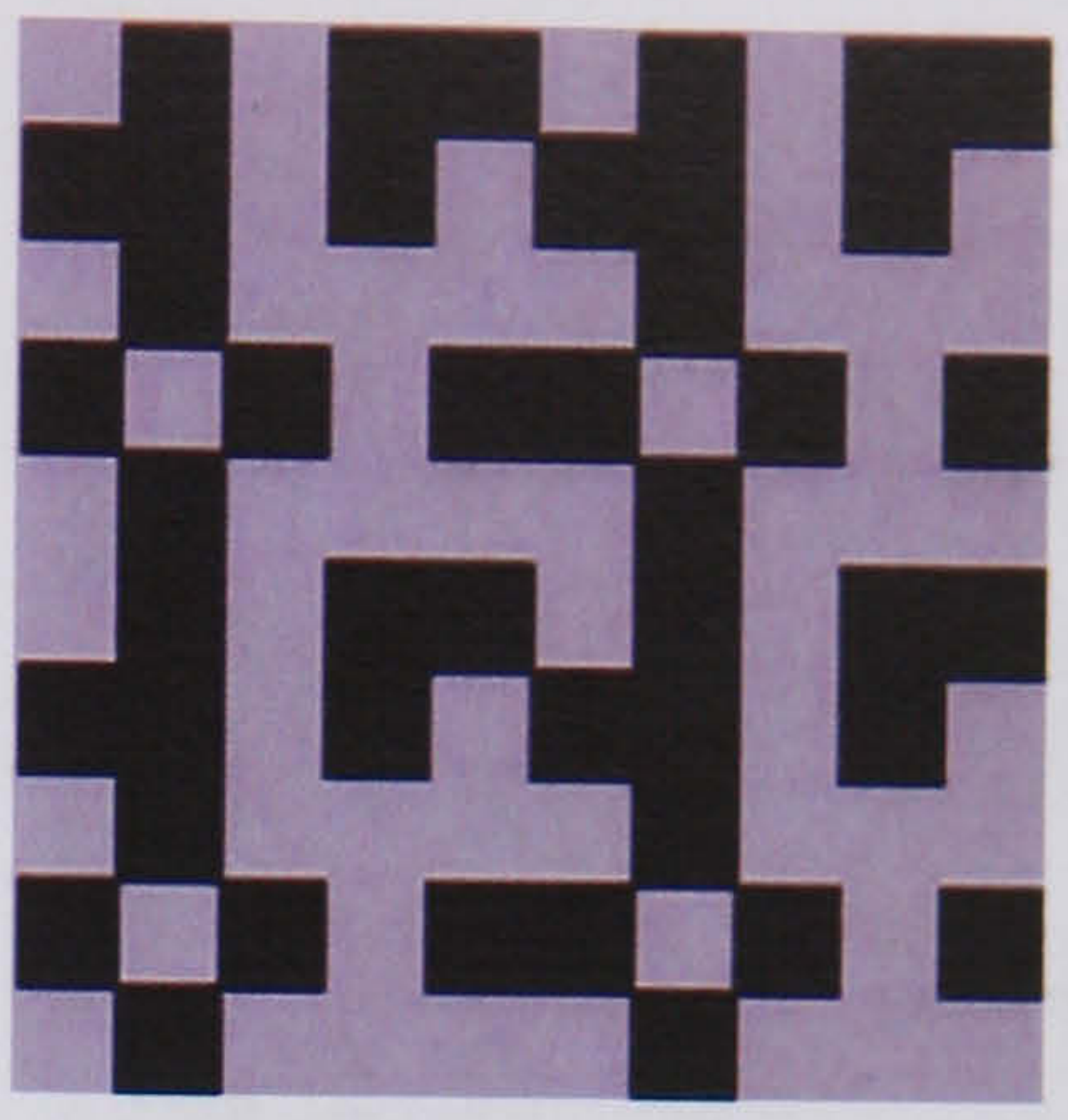


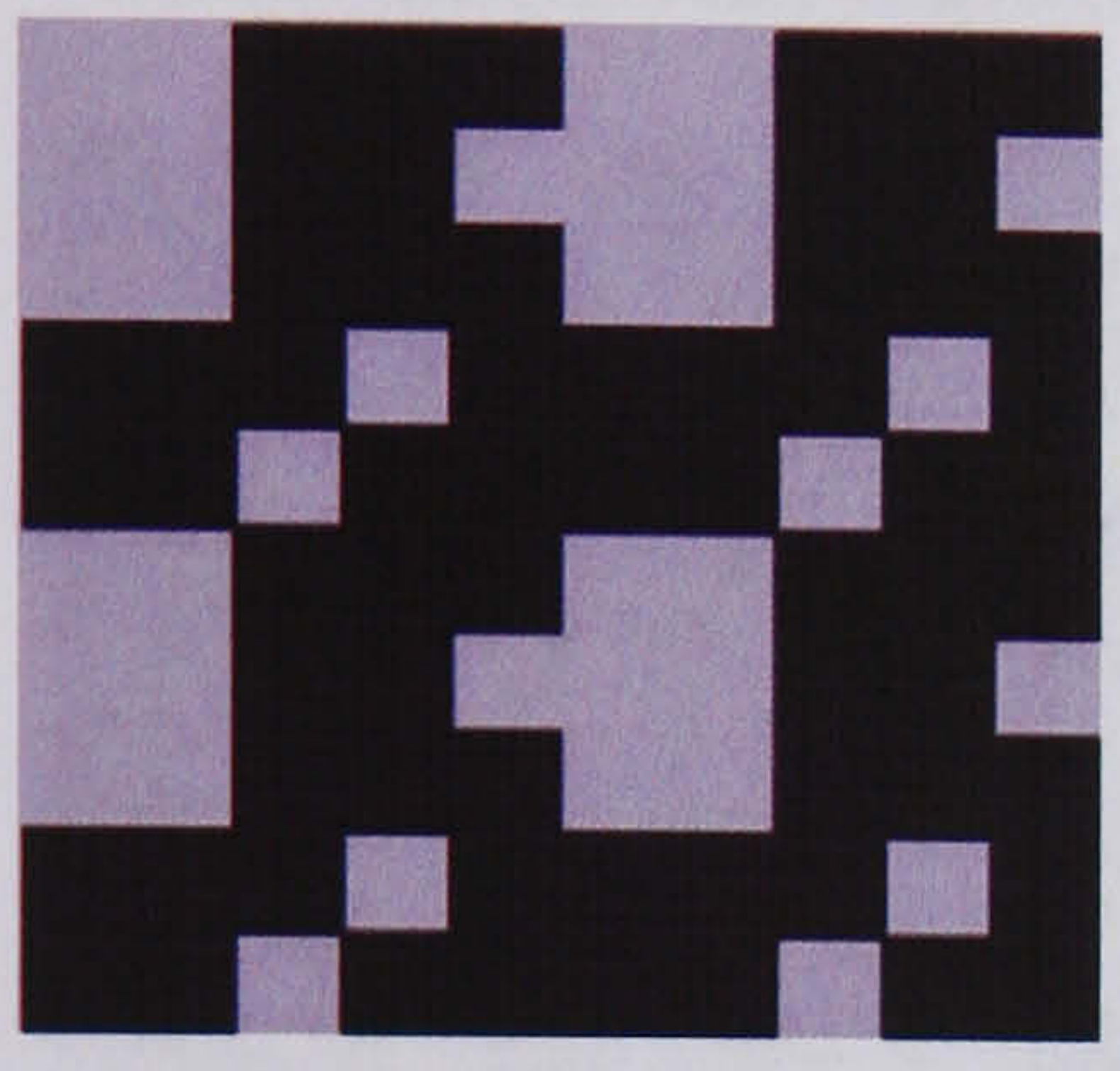
Test stimuli were also presented in negative to counter balance for differences in luminance and in all 4 rotations.

v) REPETITION (Patterns based upon 10 x 10 grids)

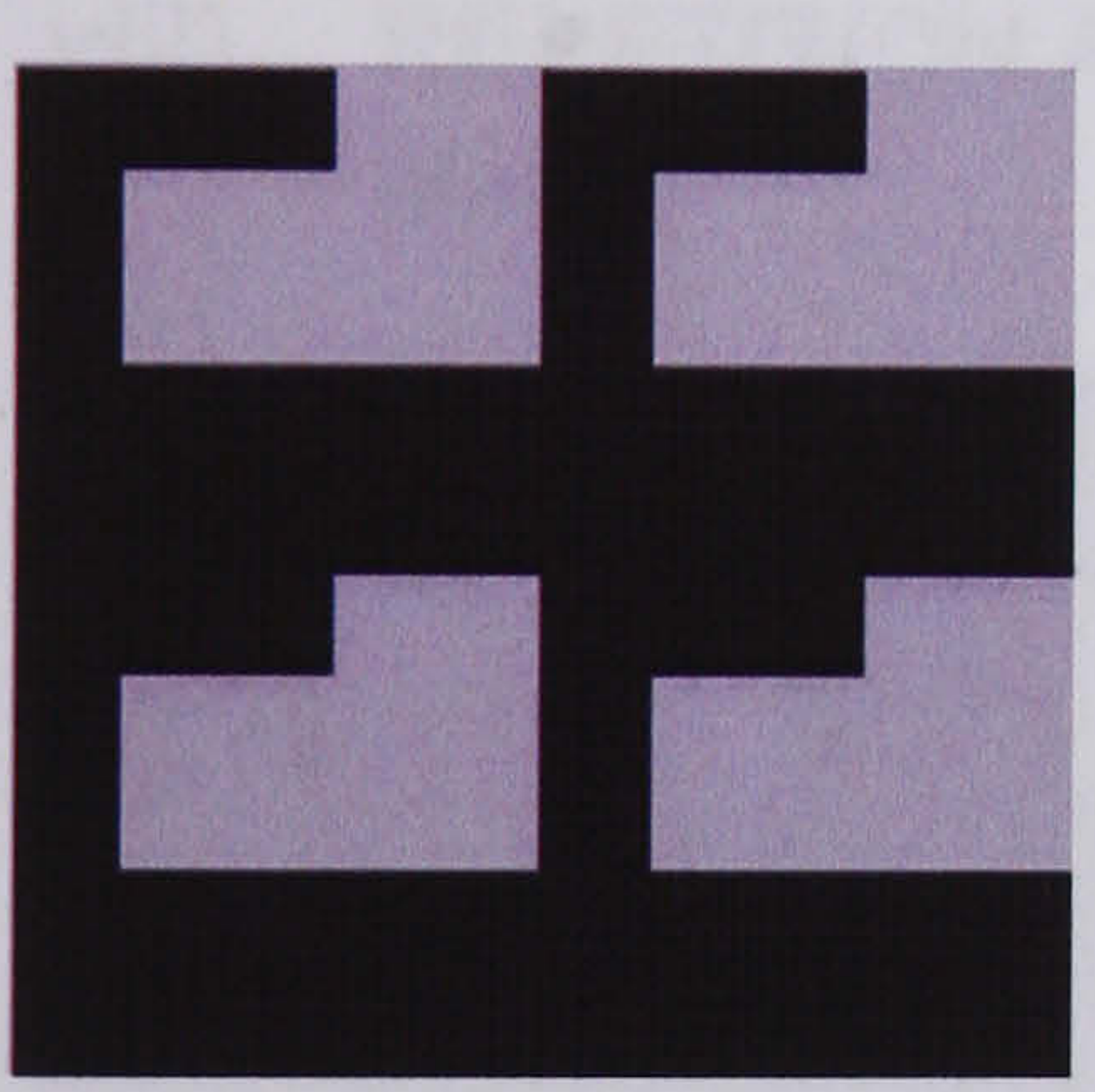


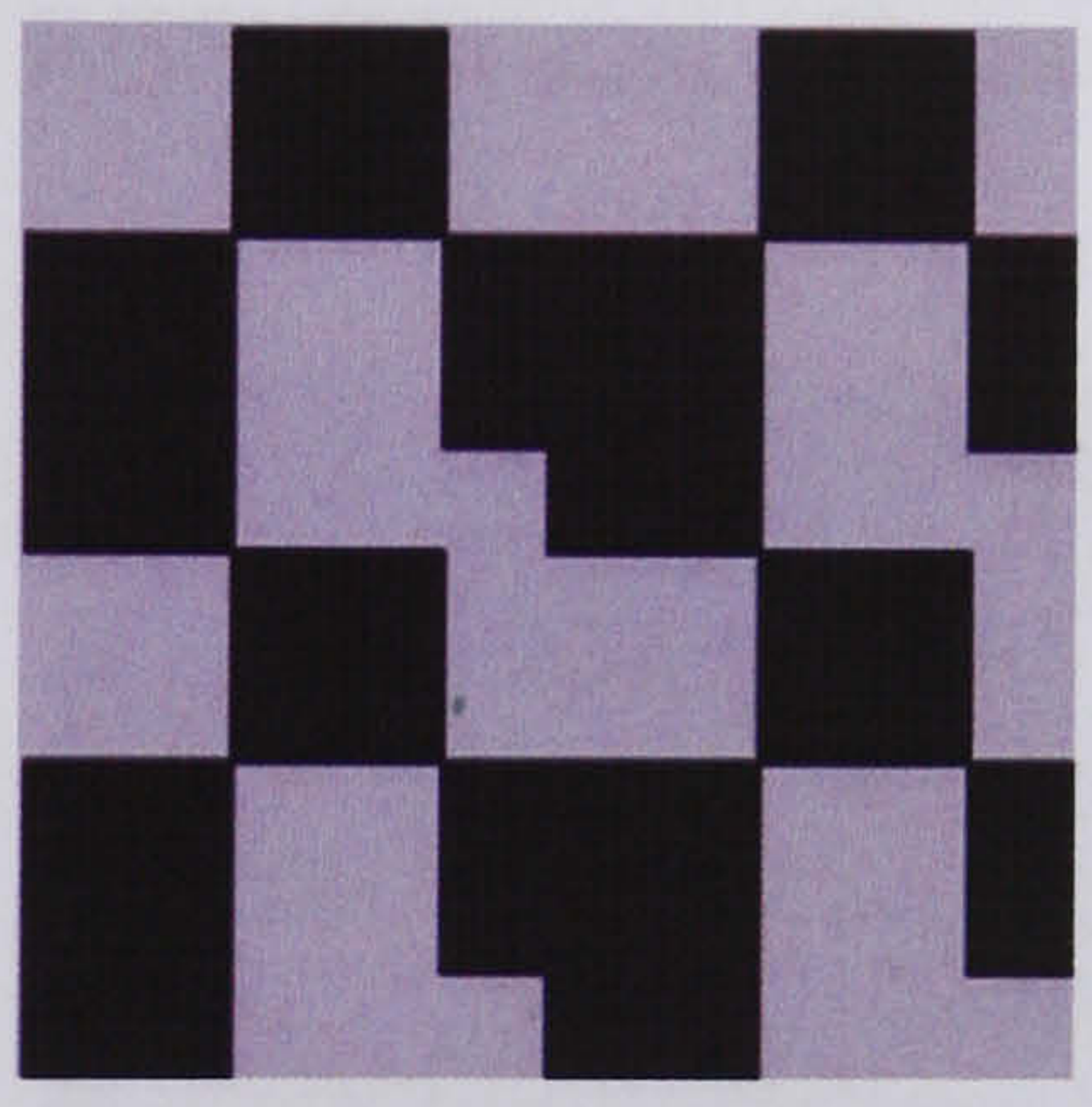


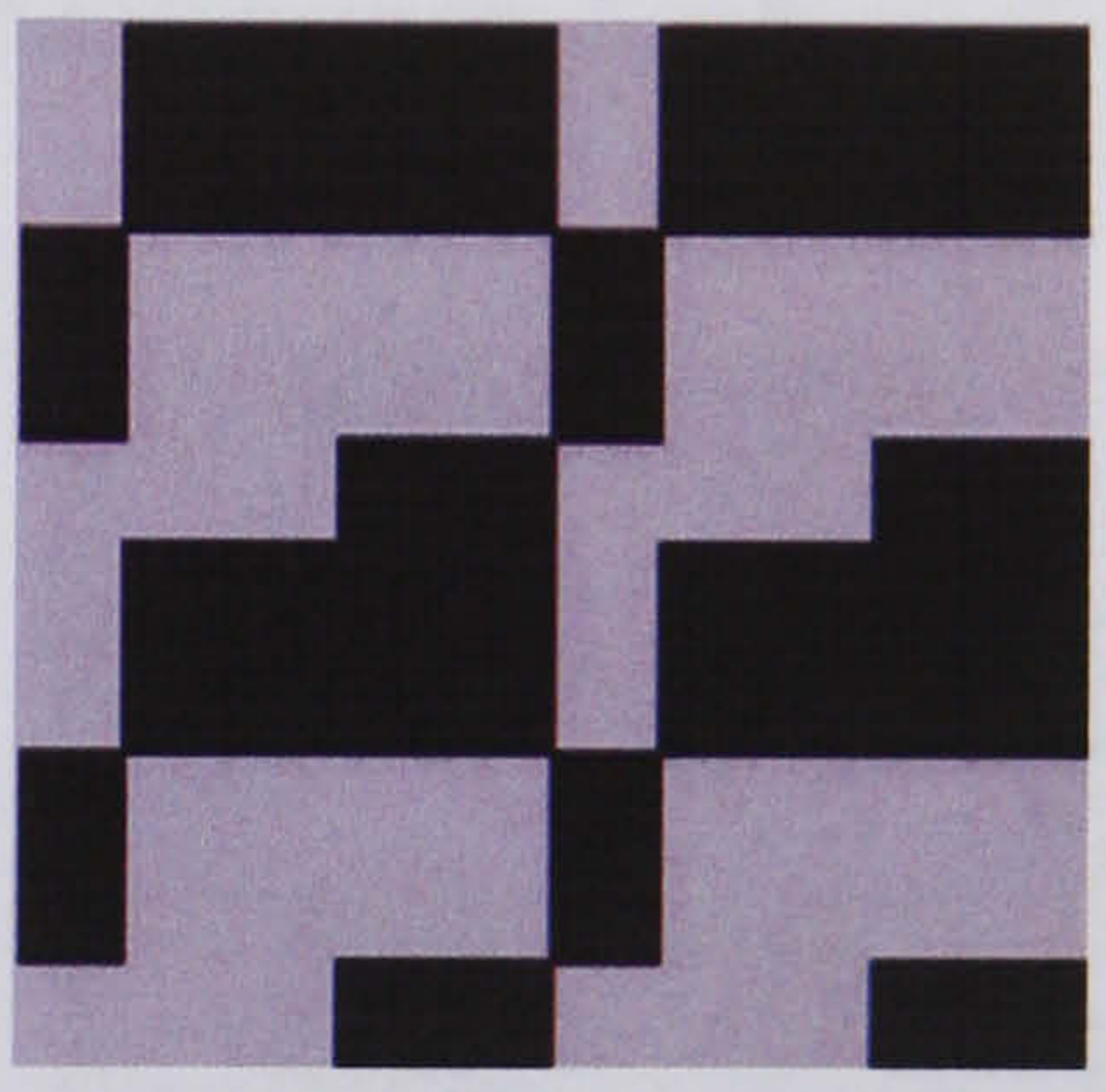


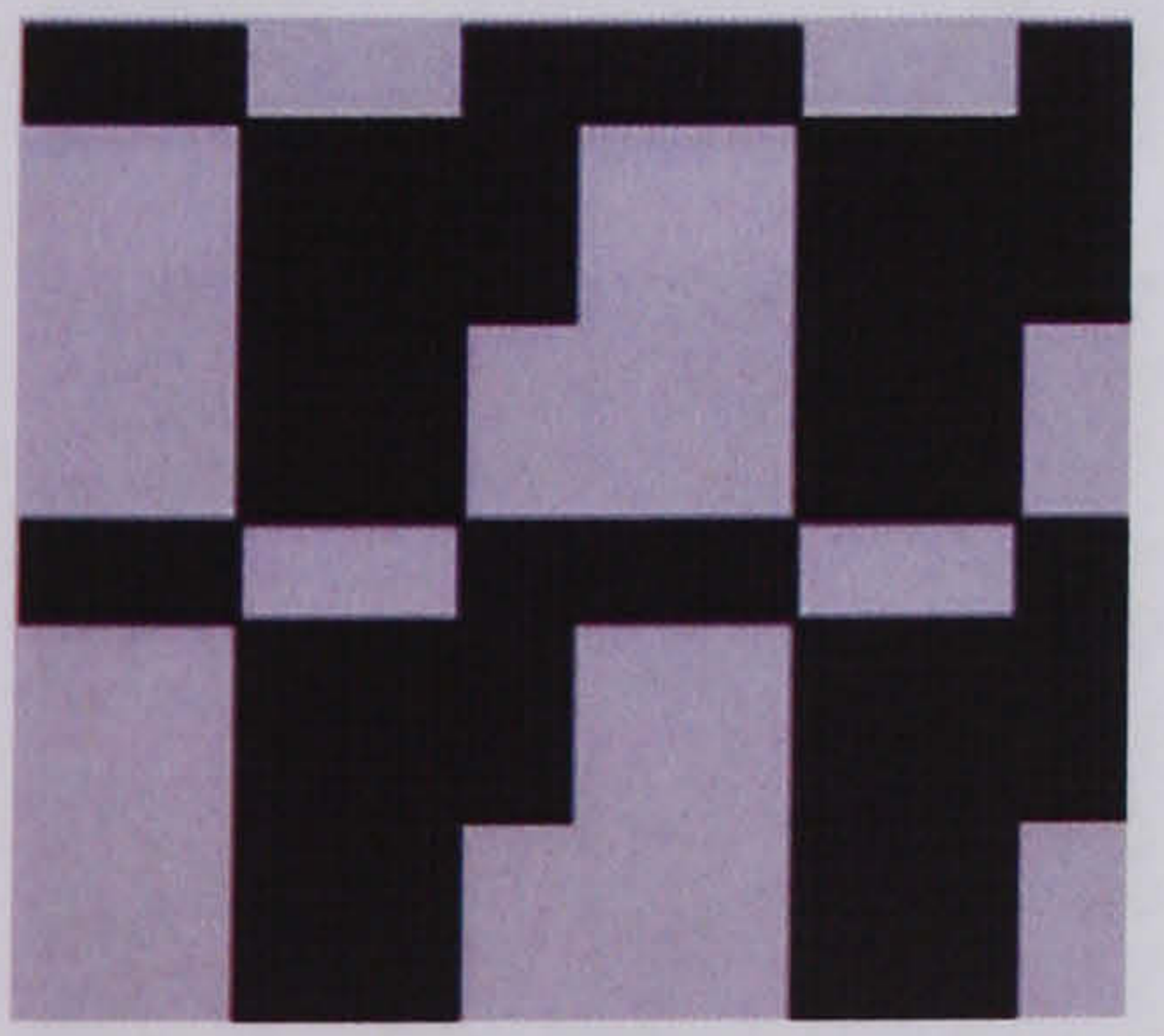


vi) REPETITION (Patterns based upon 5 x 5 grids)



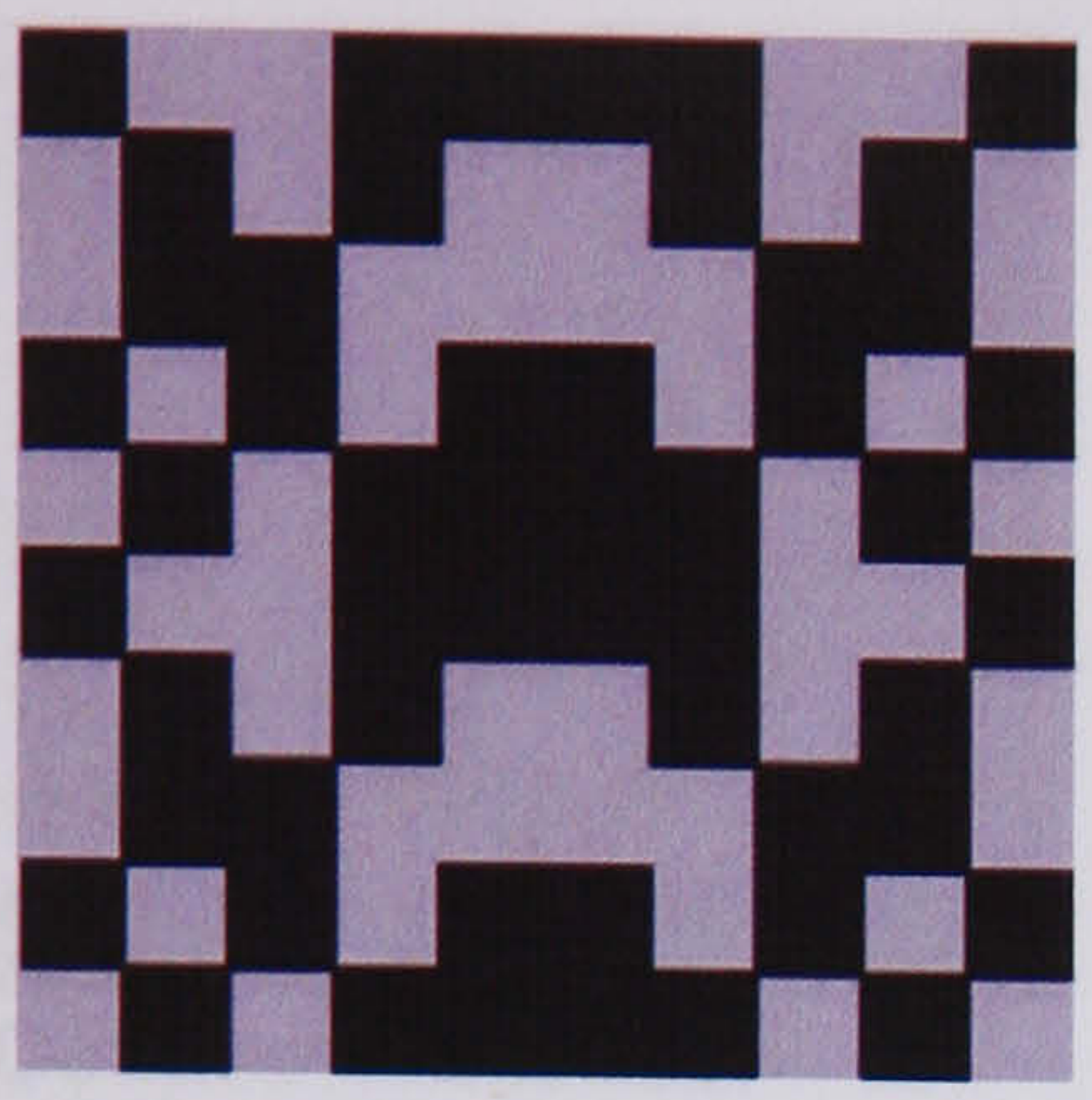


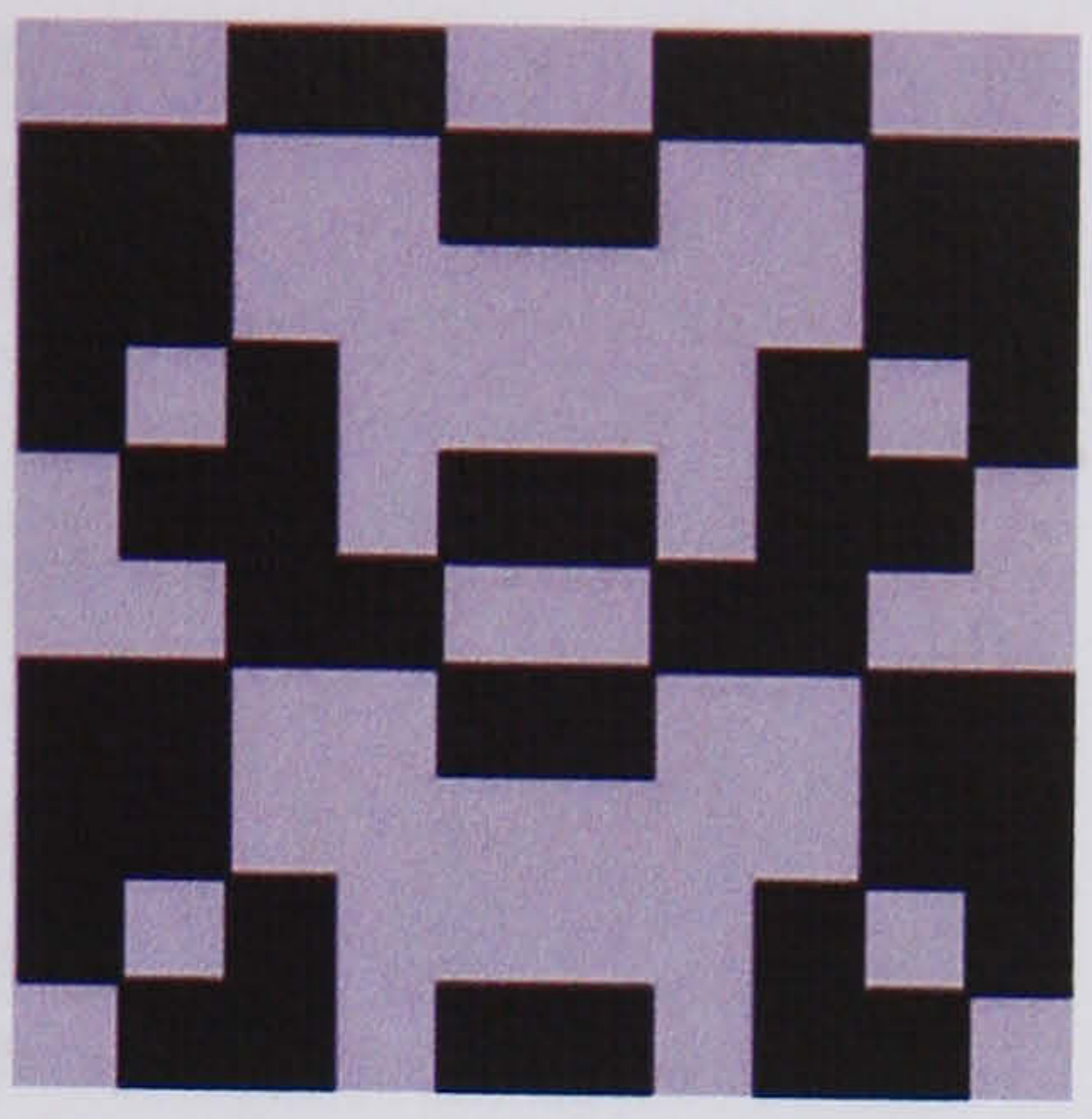


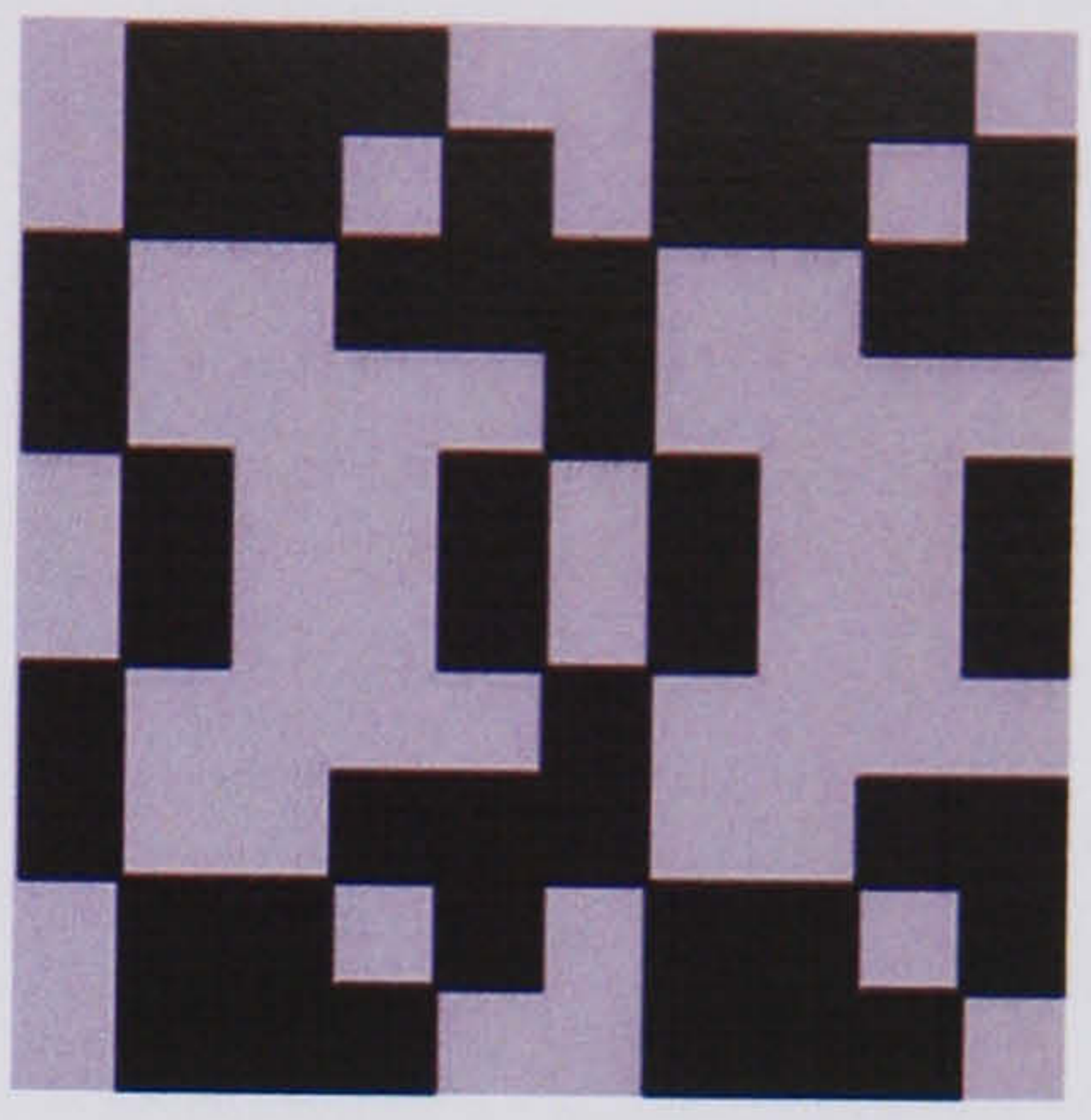


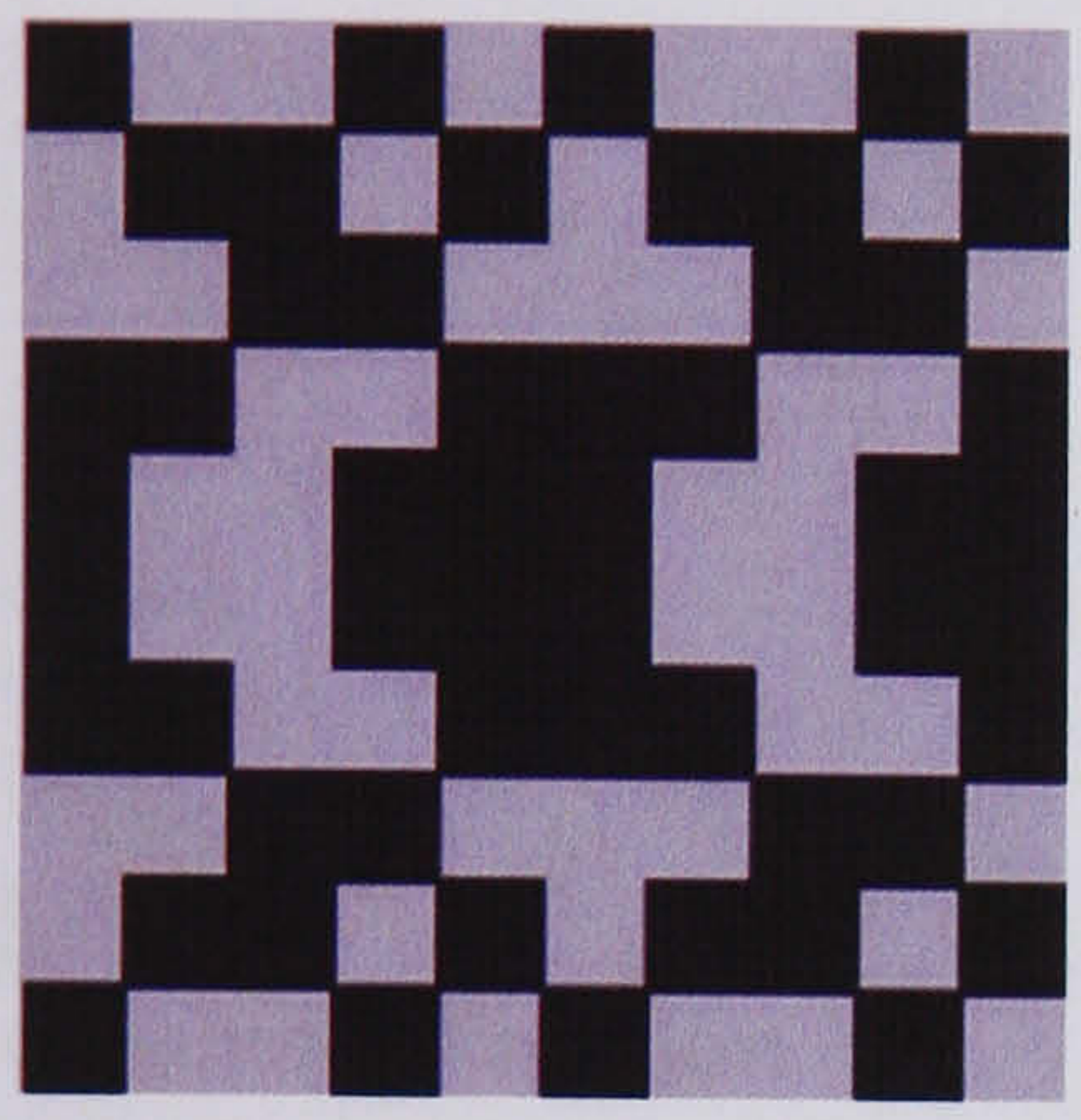
Test stimuli were also presented in negative to counter balance for differences in luminance and in all 4 rotations.

vii) REPETITION AND REFLECTION (Patterns based upon 10 x 10 grids)

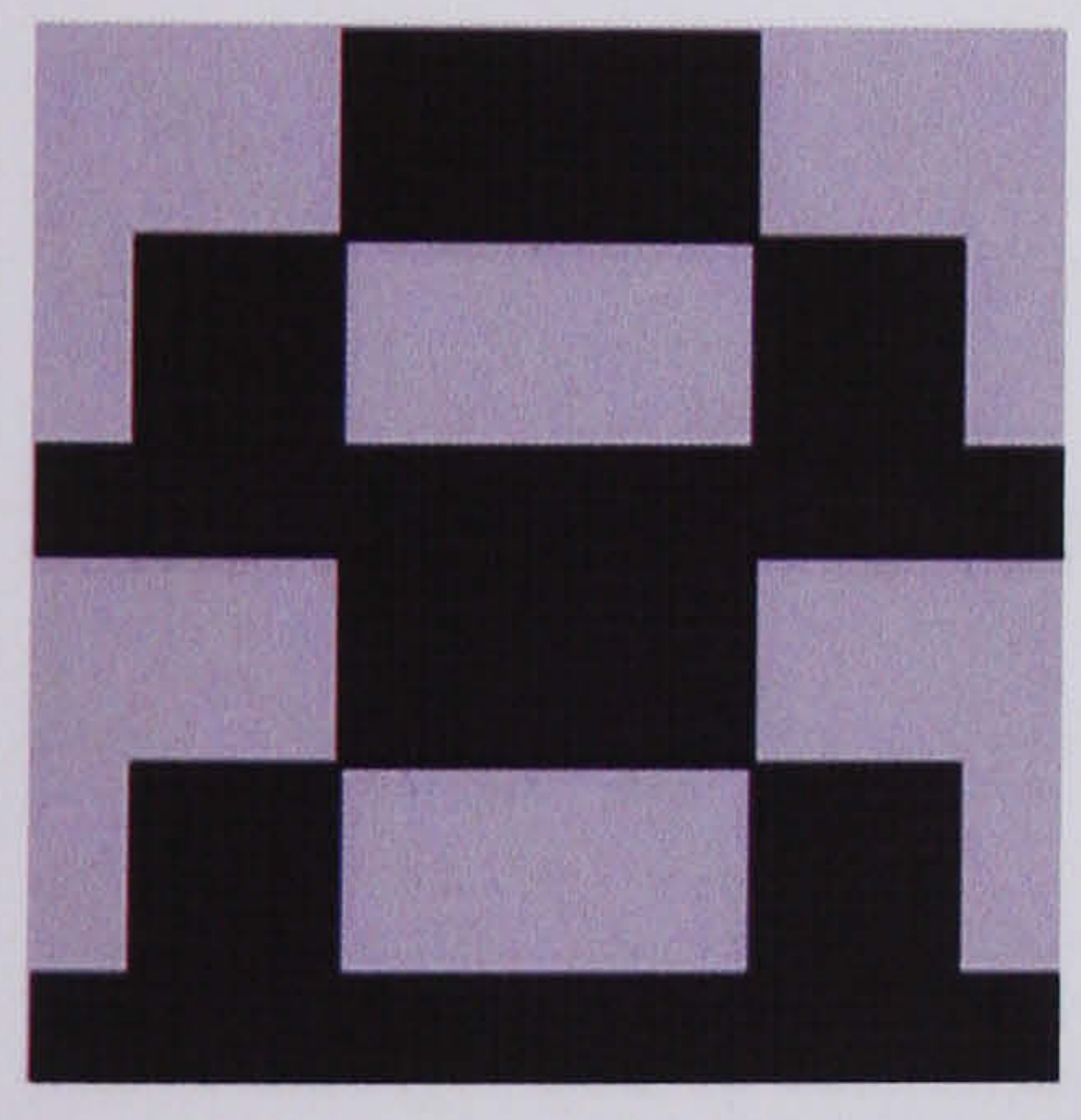


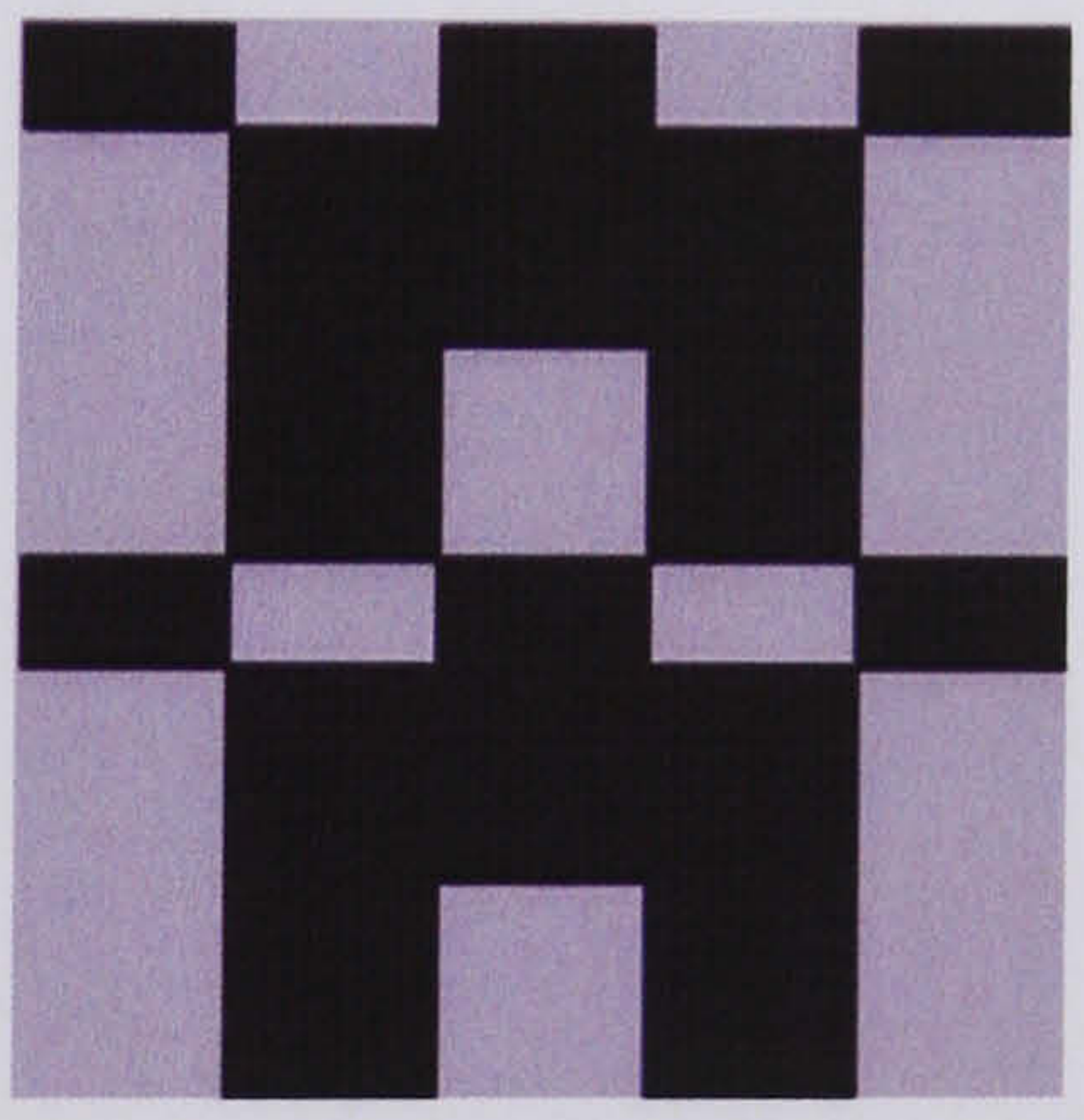


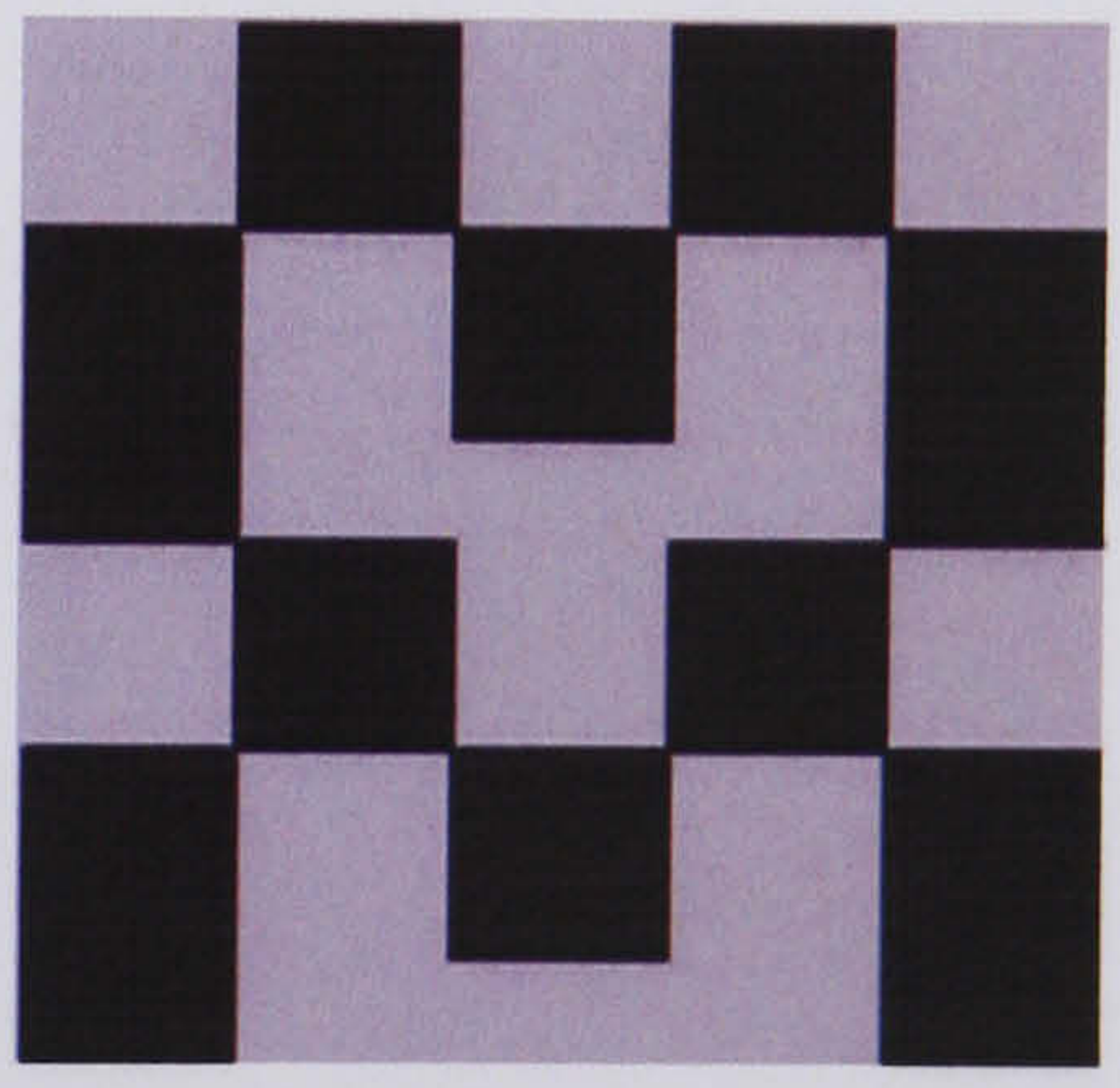


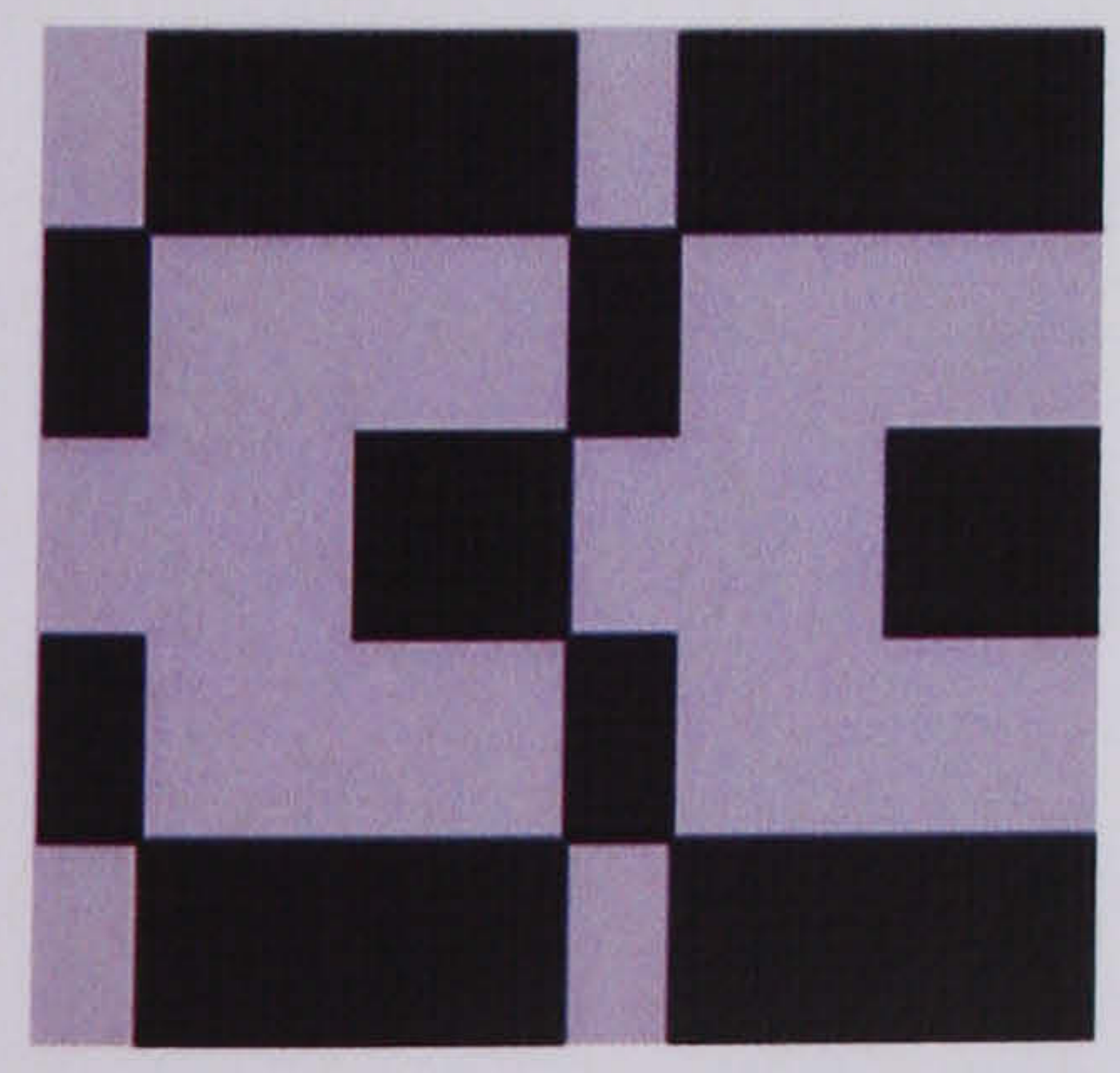


viii) REPETITION AND REFLECTION (Patterns based upon 5 x 5 grids)



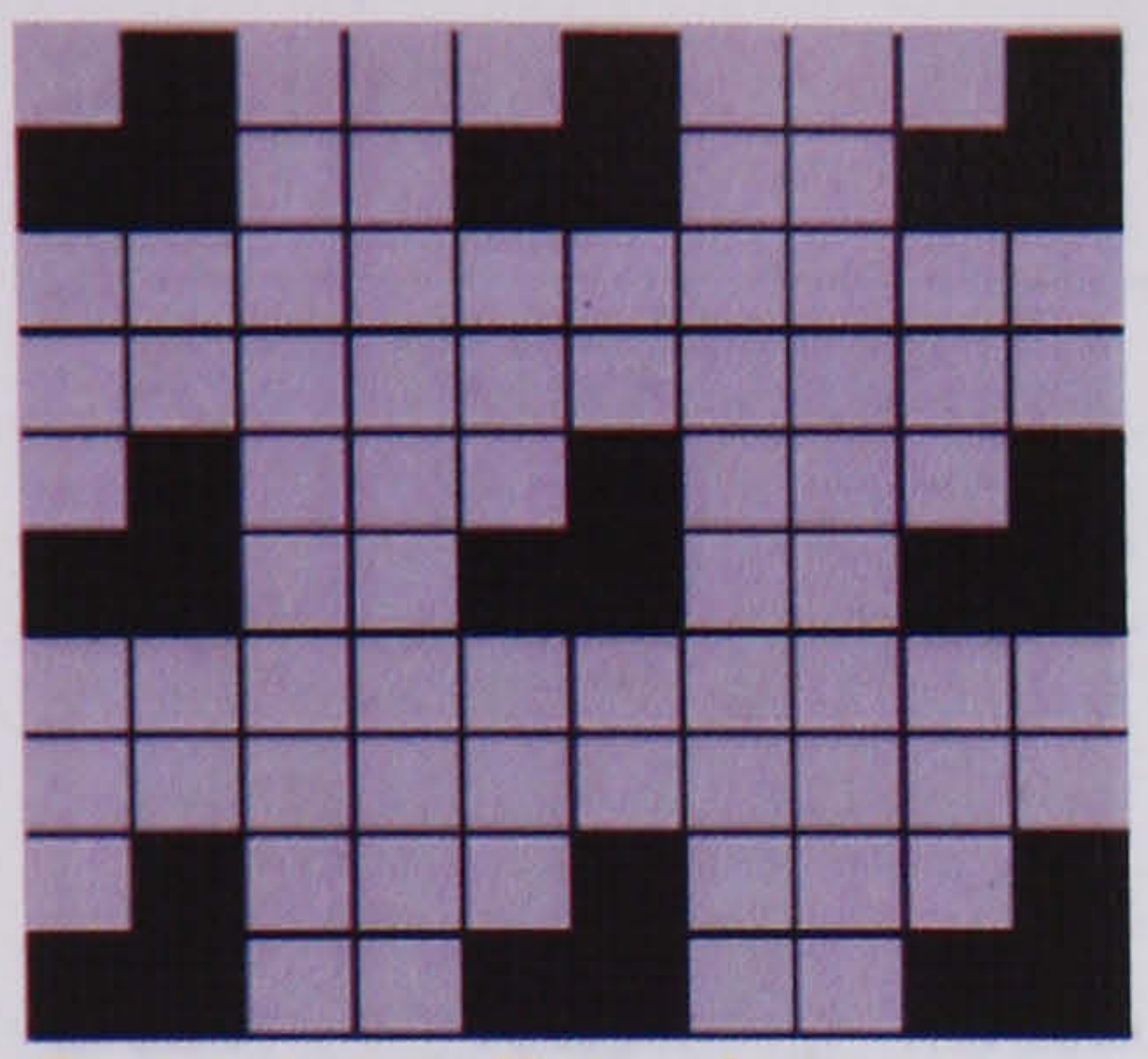




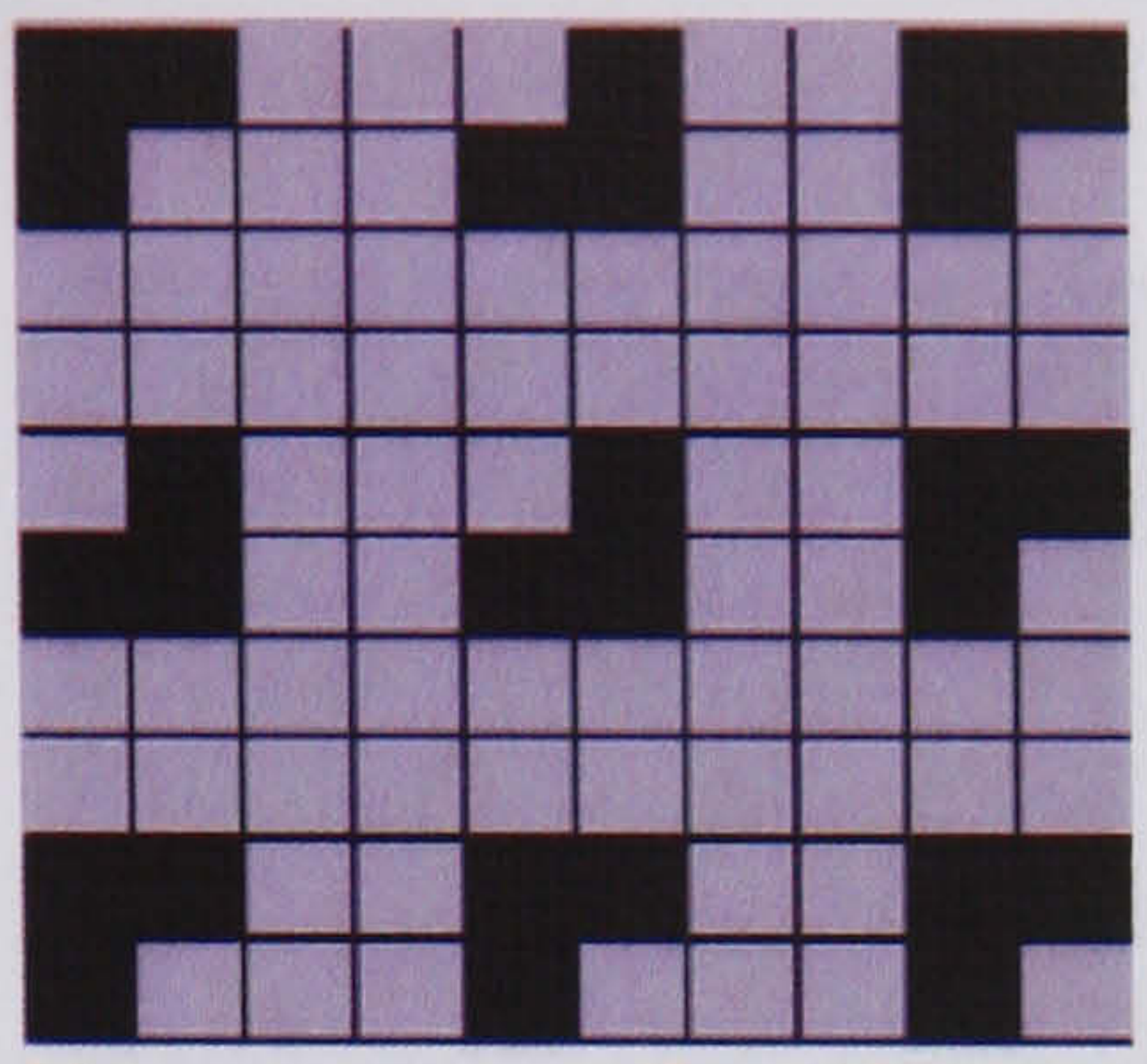


Test stimuli were also presented in negative to counter balance for differences in luminance and in all 4 rotations.

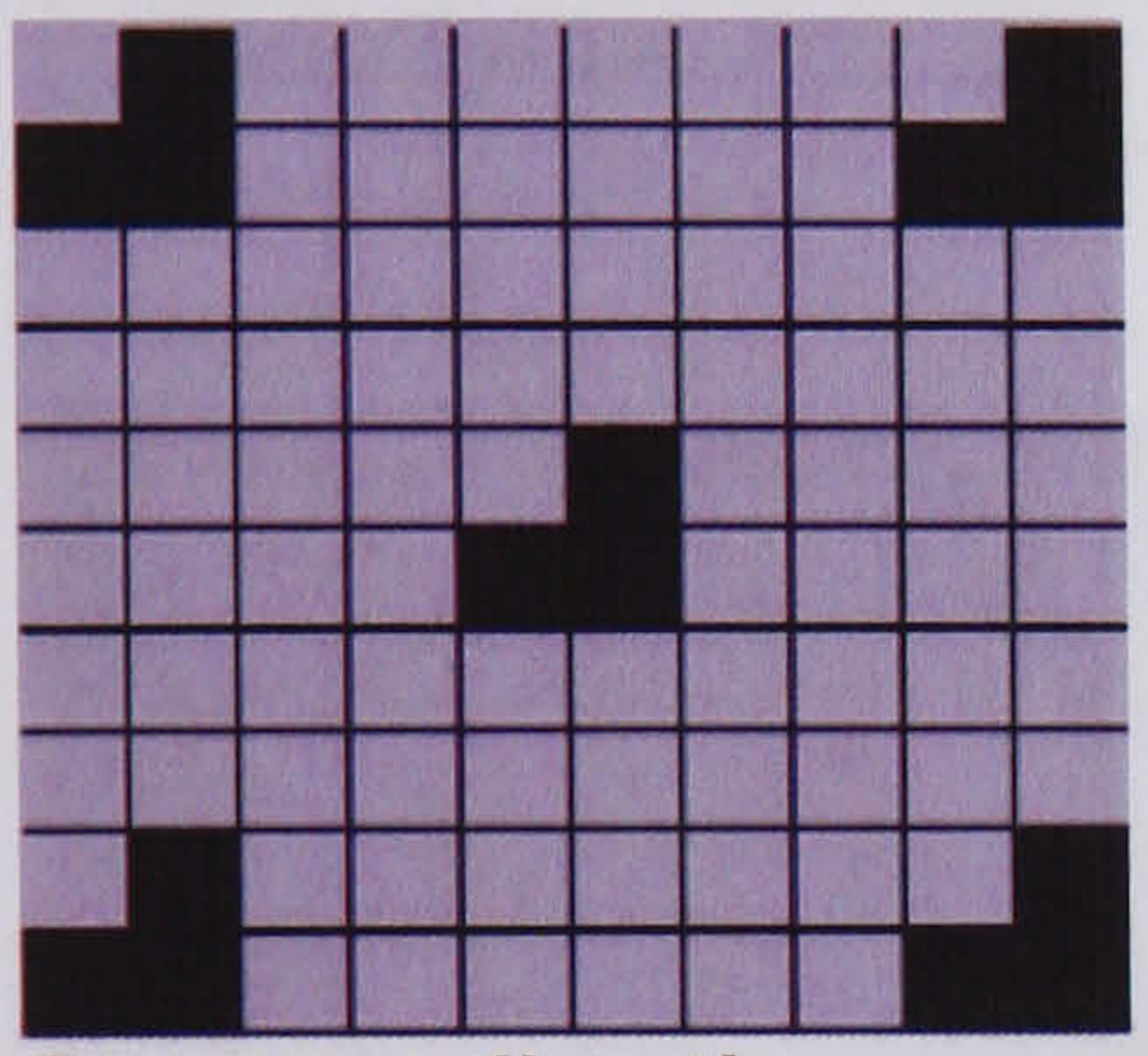
B) Common Direction



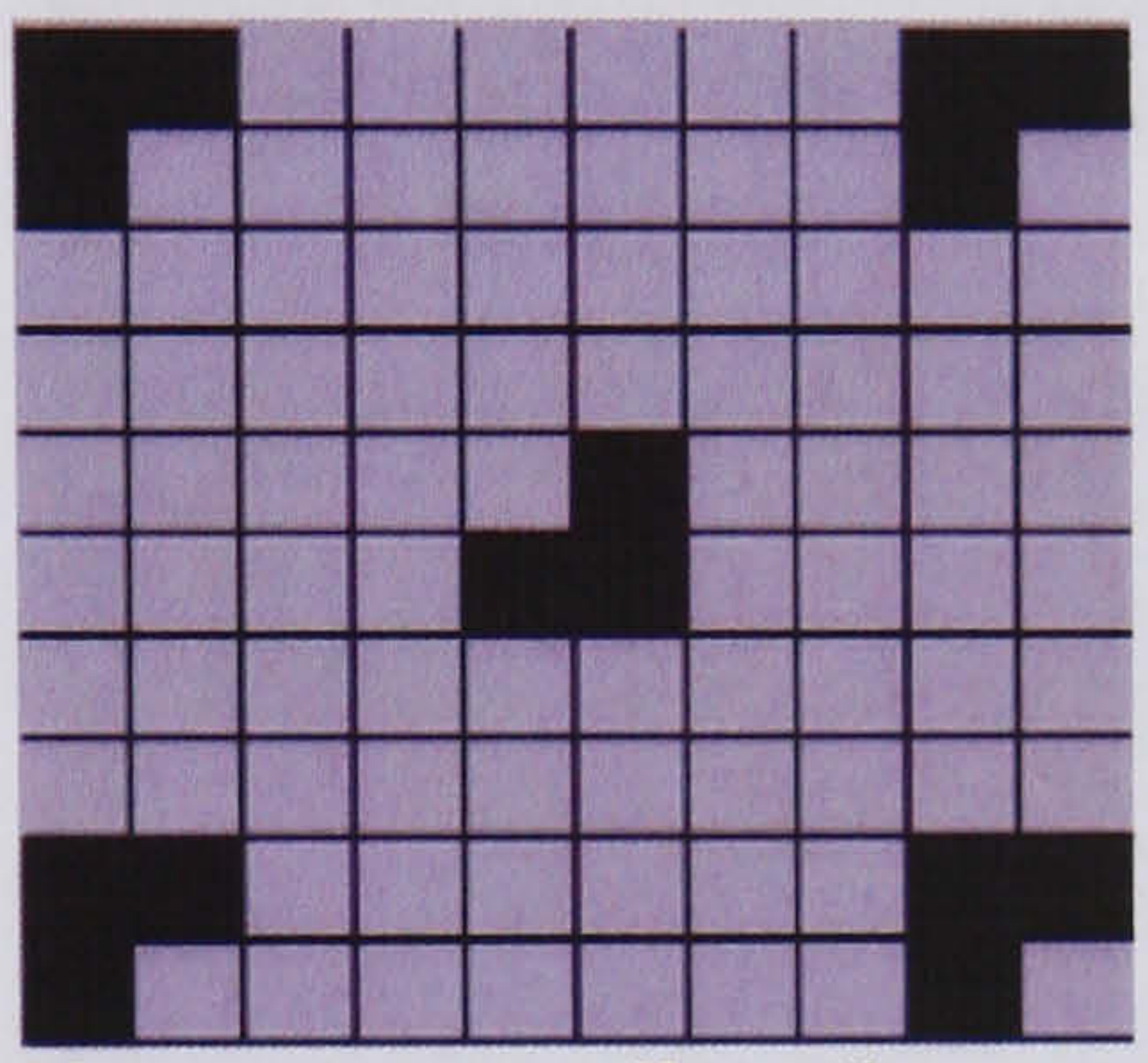
Common direction



No-common direction



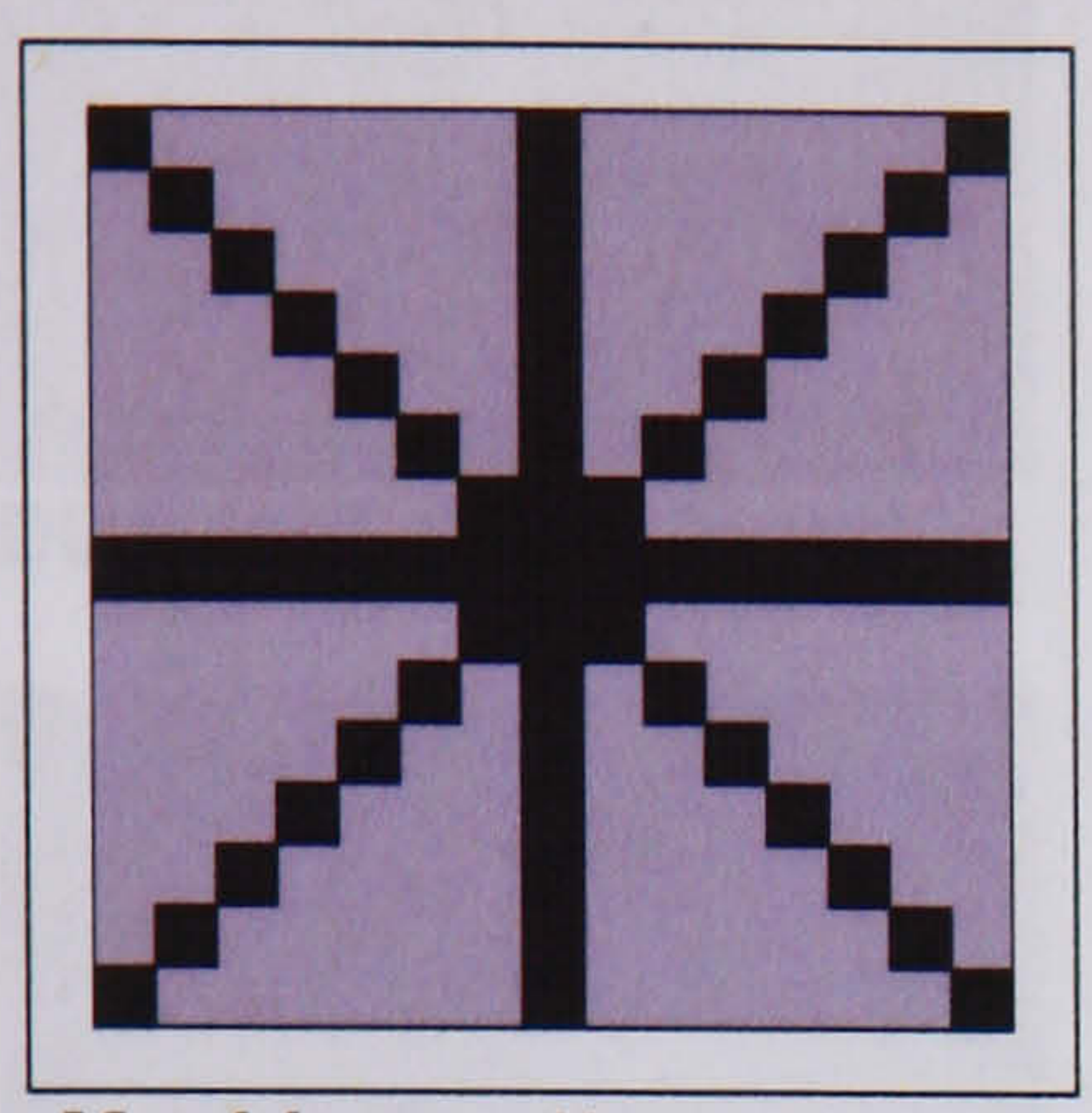
Common direction

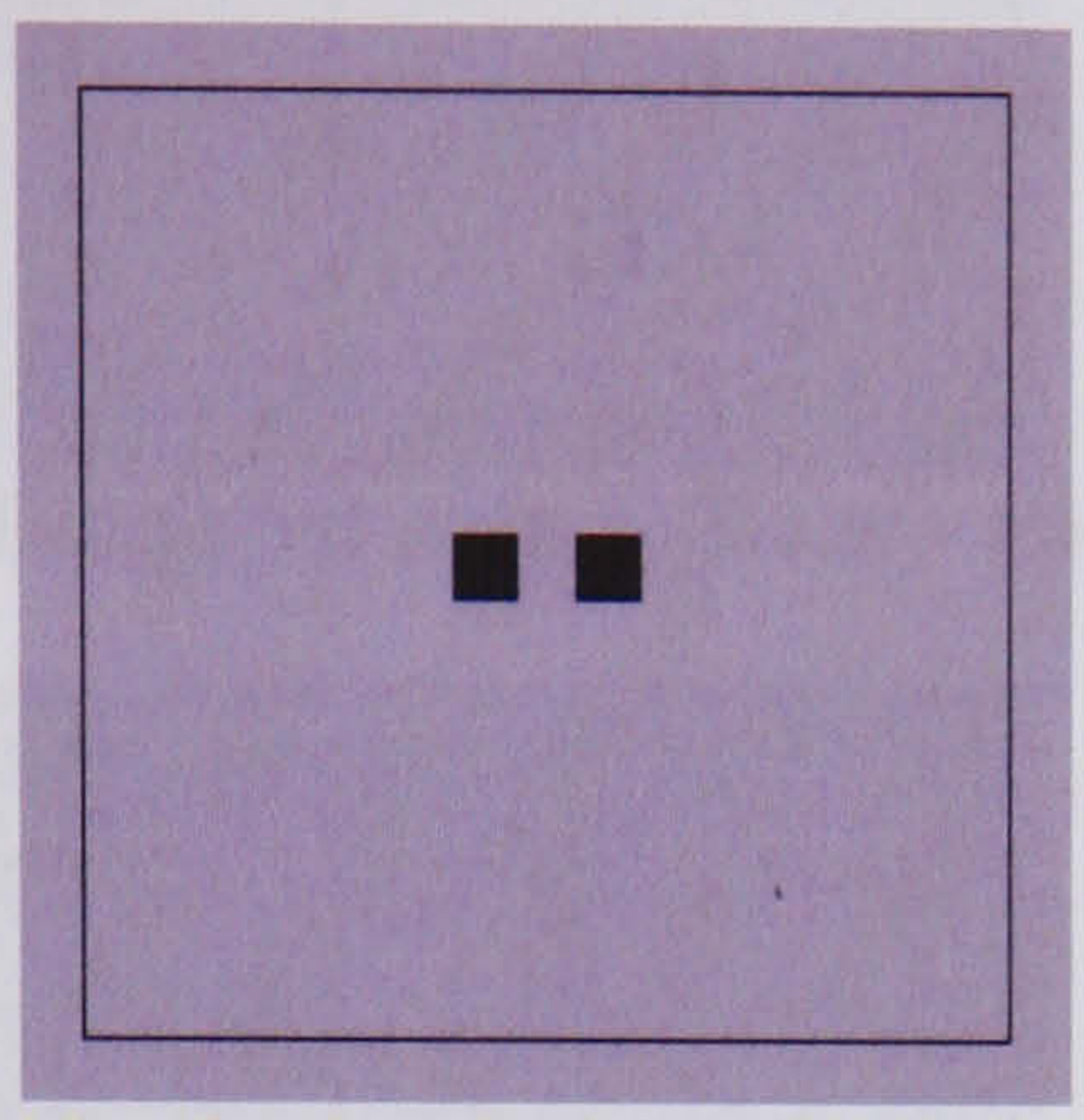


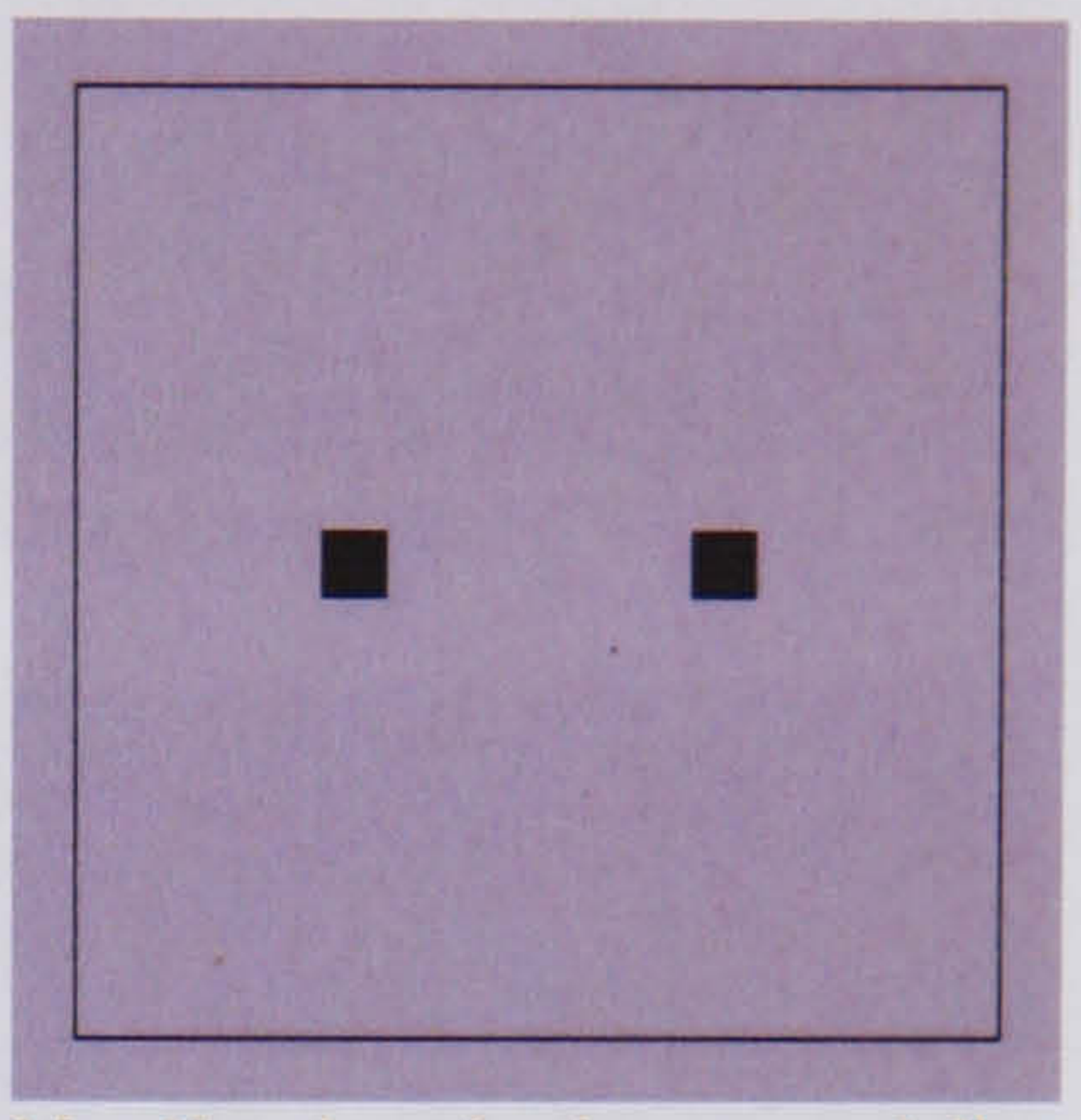
No common direction

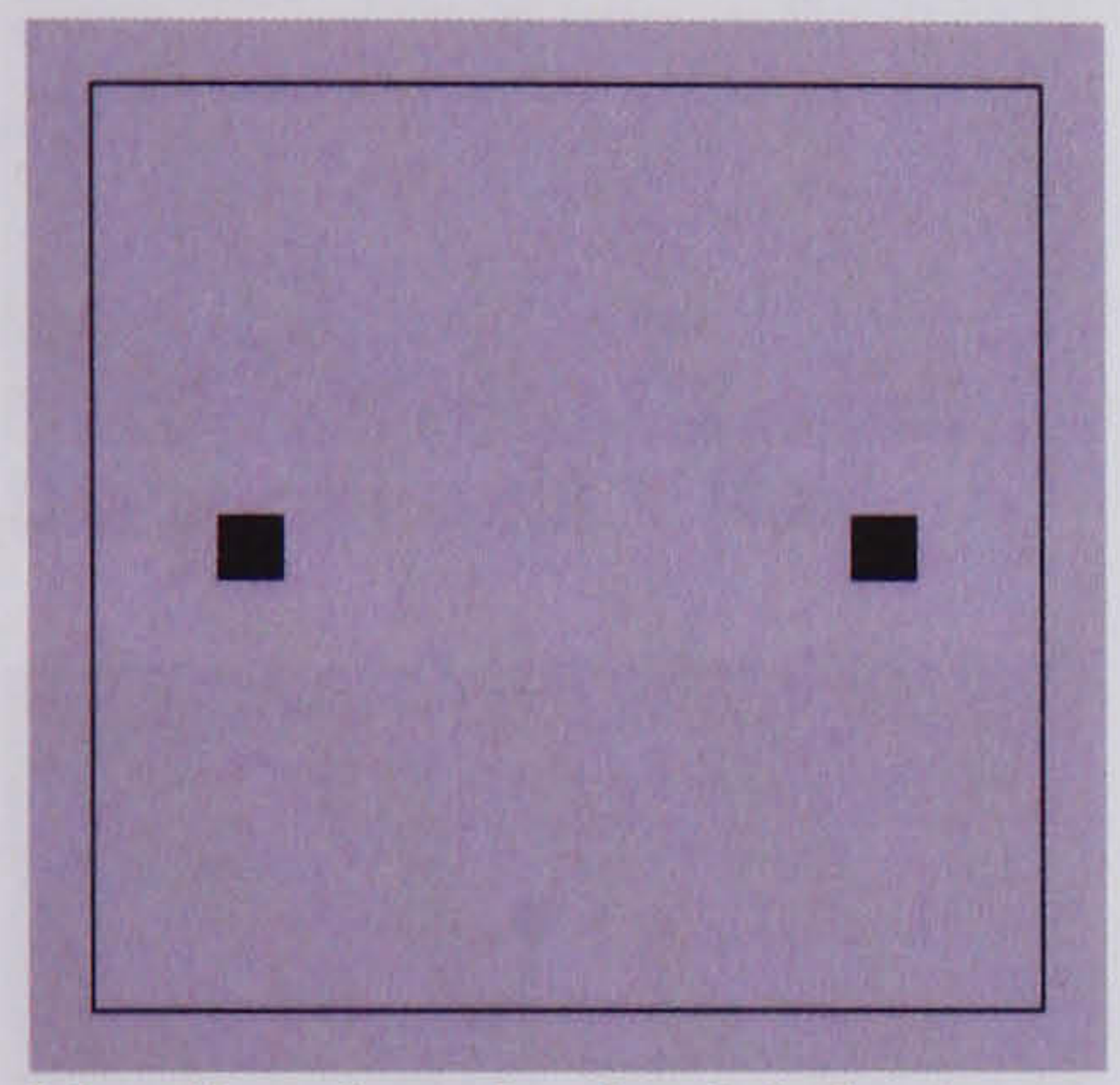
C) Axis of reflection

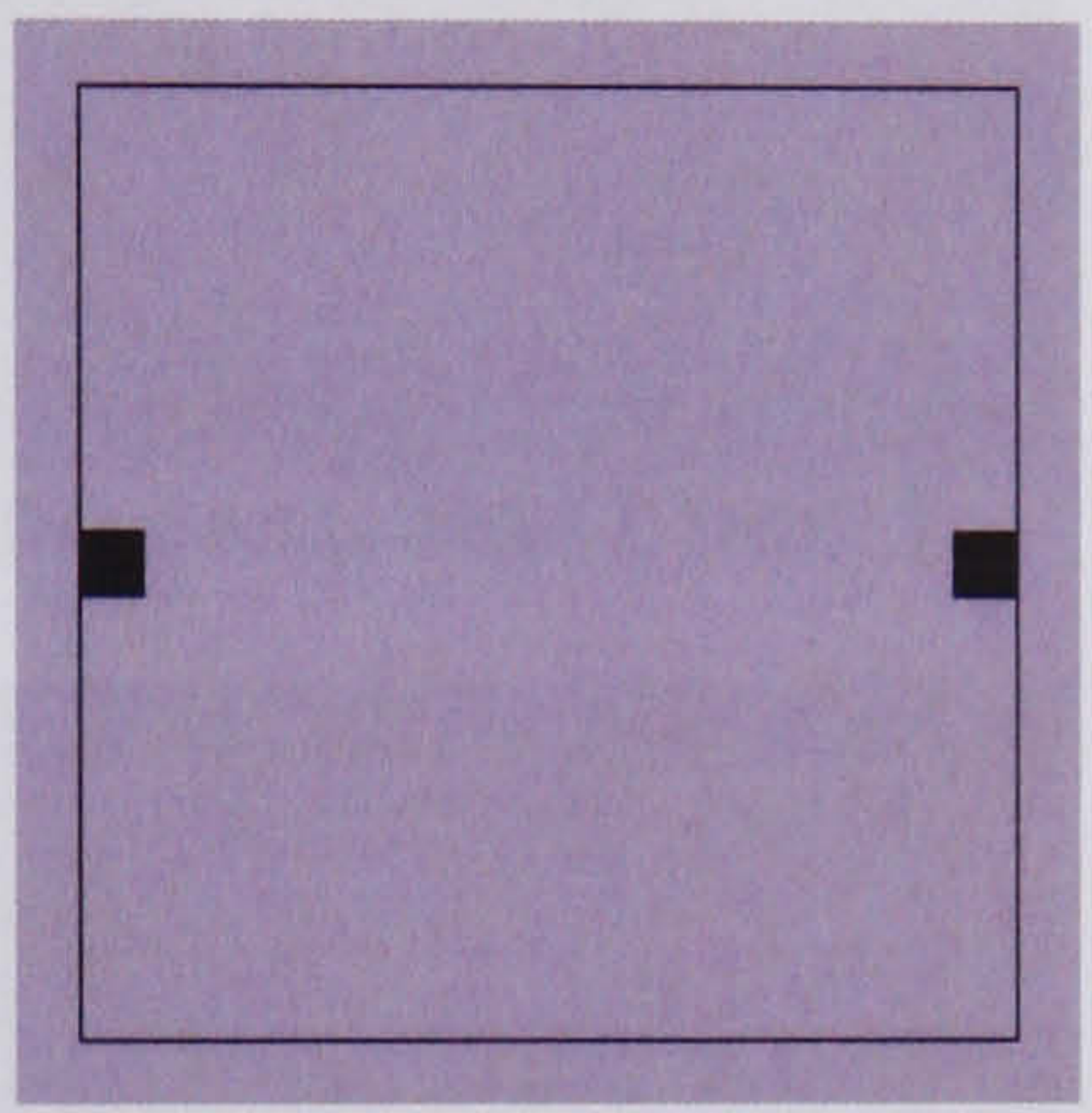
Each pattern is labelled by the axis of reflection and the distance condition in brackets

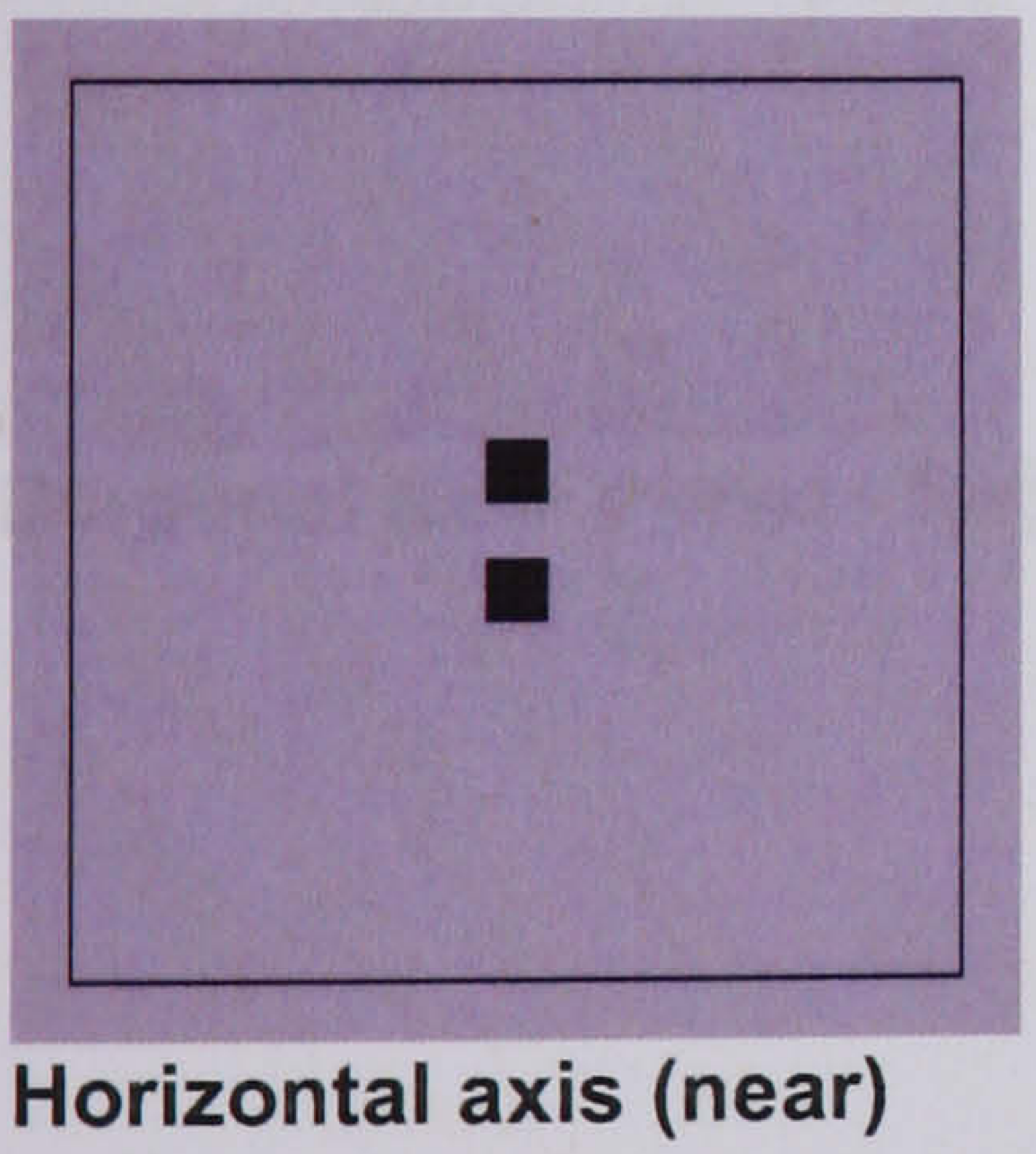

Masking pattern

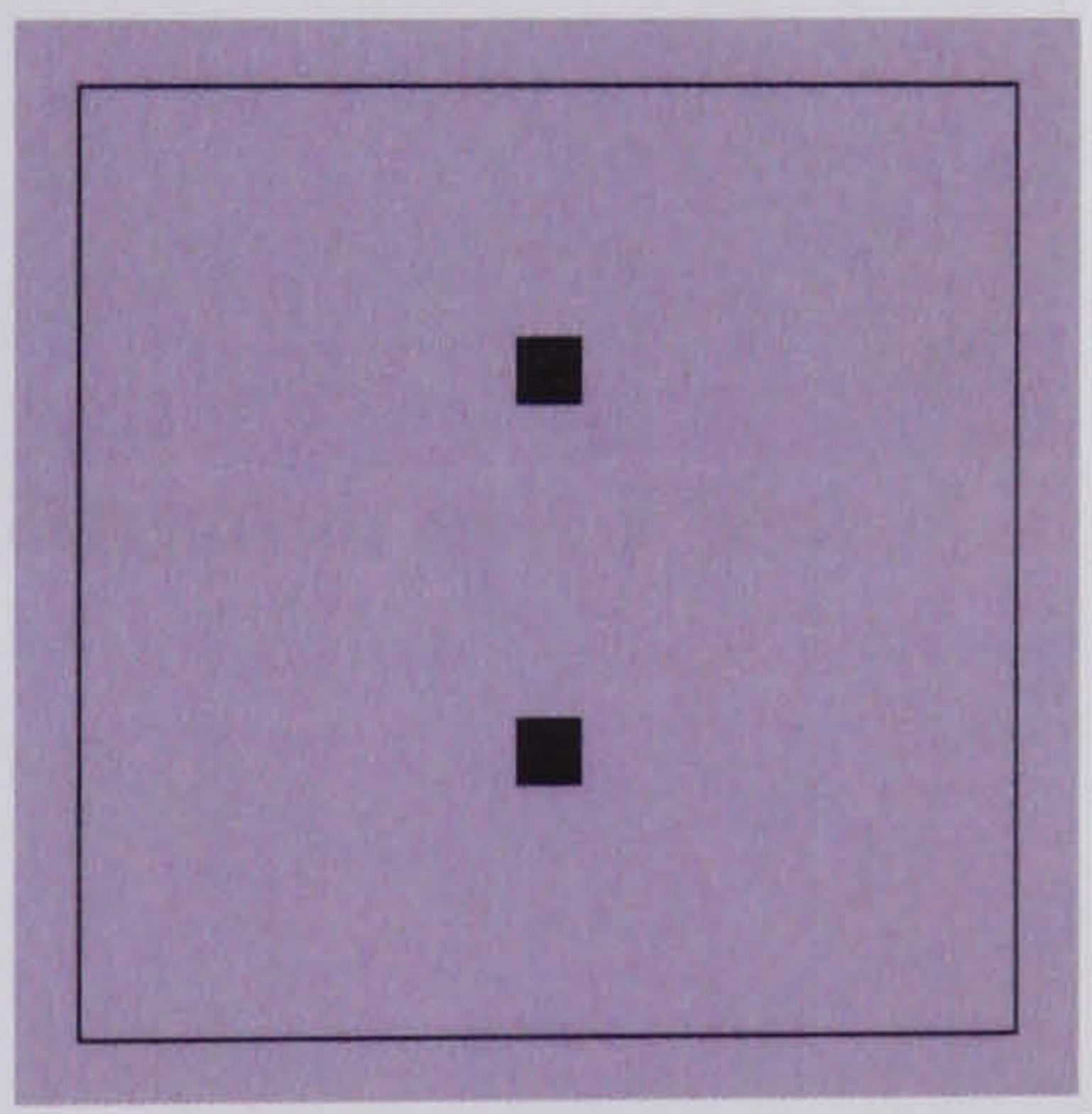

Vertical axis (near)

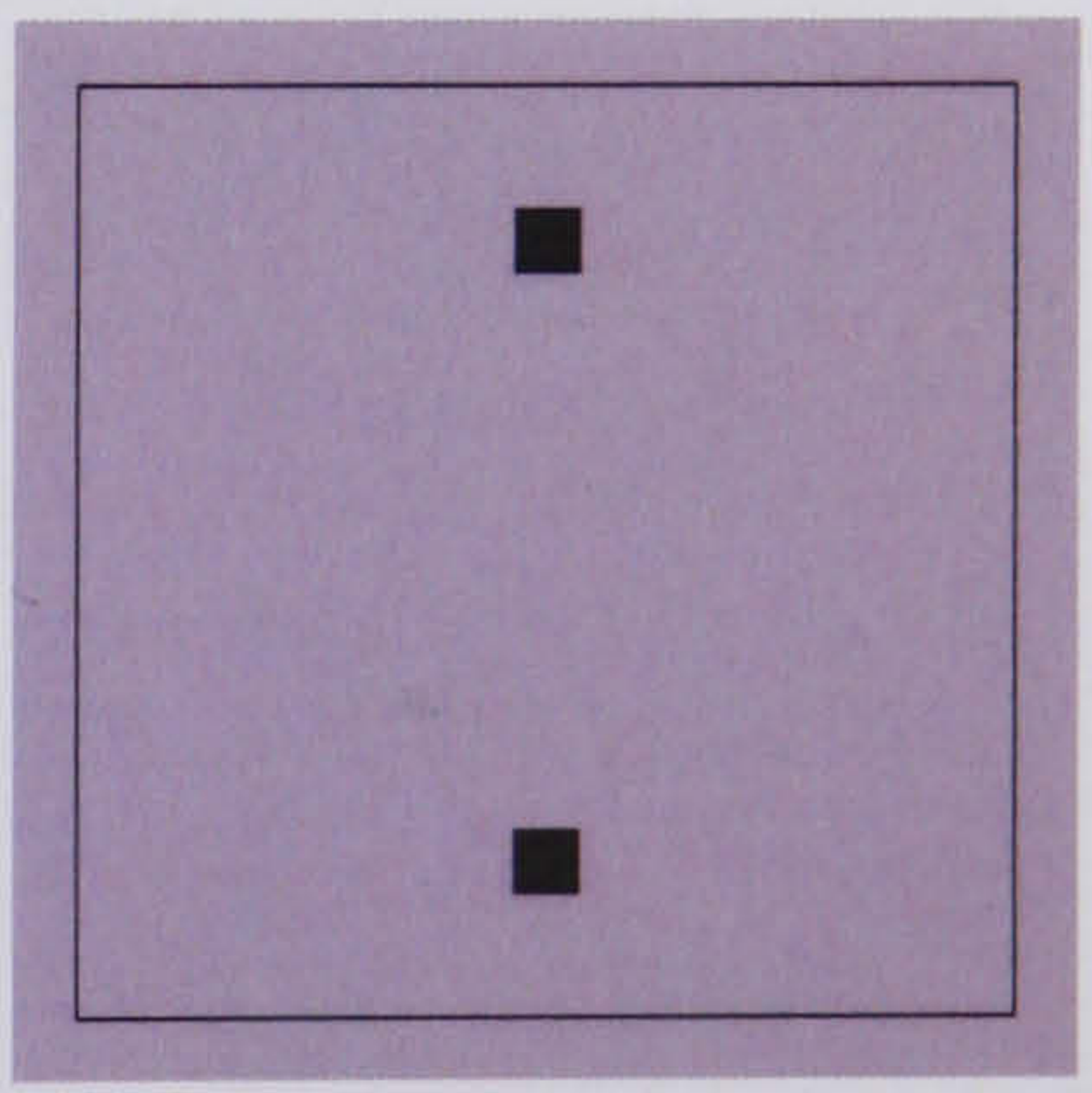

Vertical axis (near-mid)

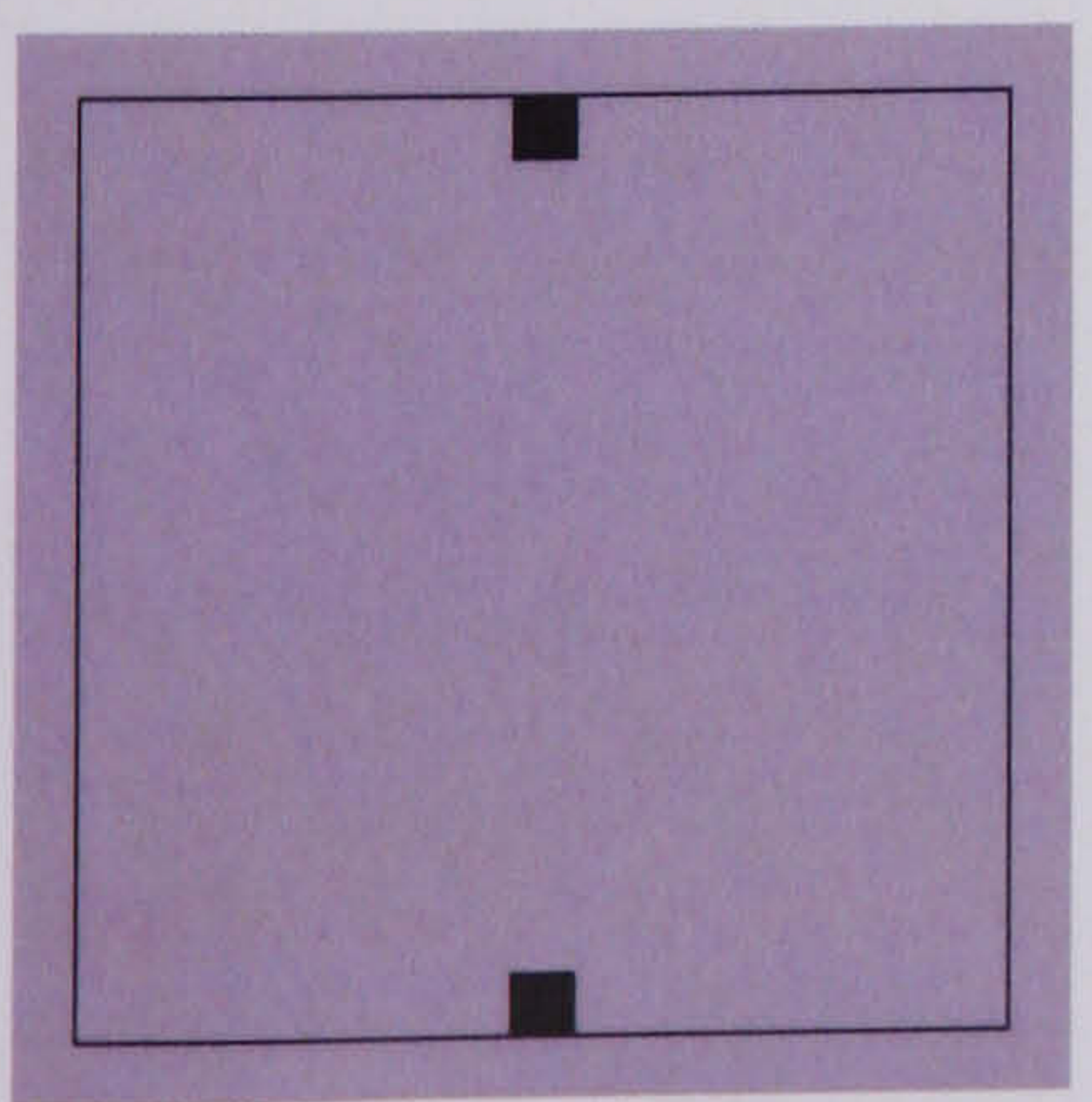

Vertical axis (mid-far)

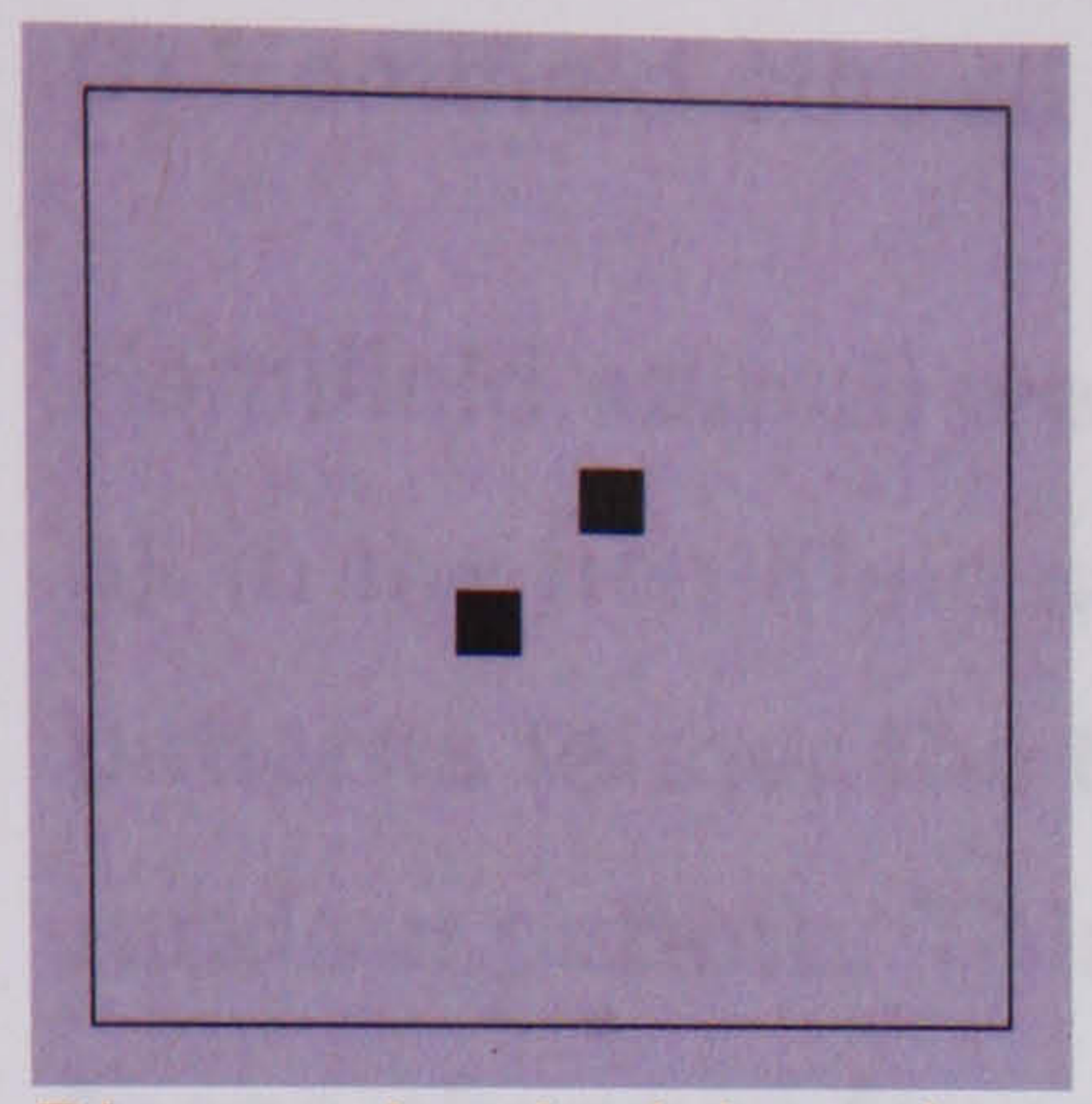

Vertical axis (far)


Horizontal axis (near)

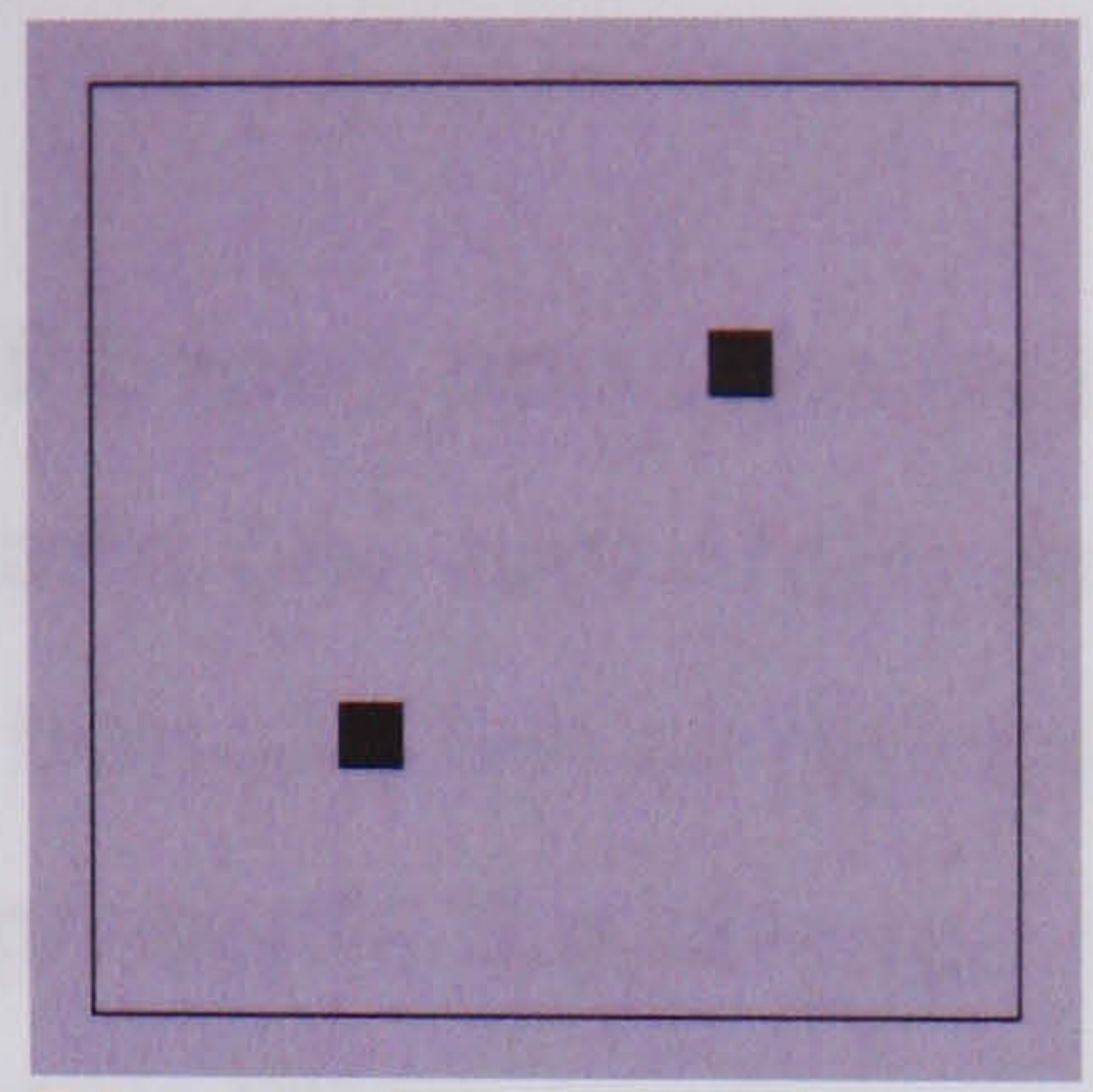

Horizontal axis (near - mid)


Horizontal axis (mid - far)

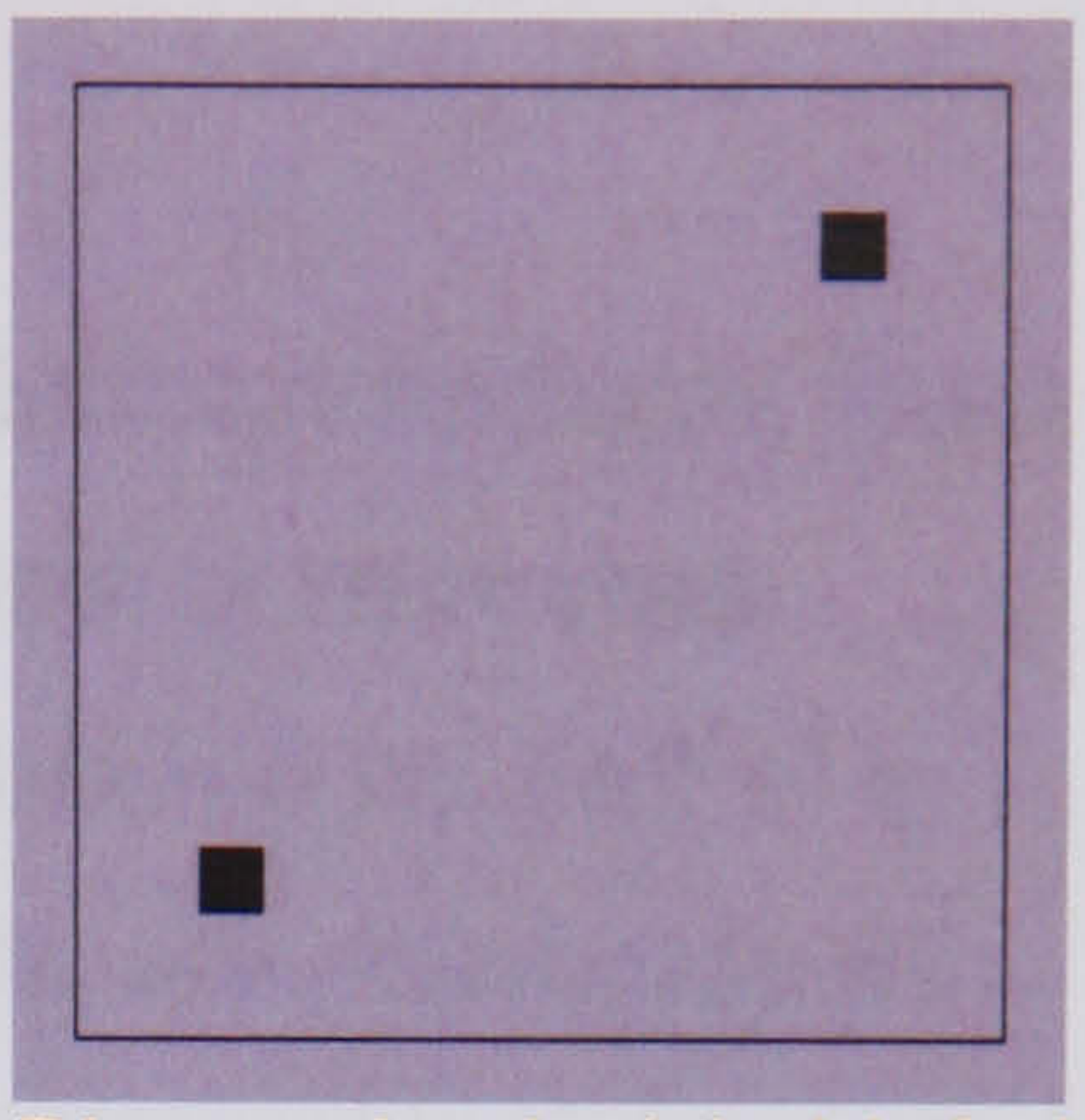

Horizontal axis (far)



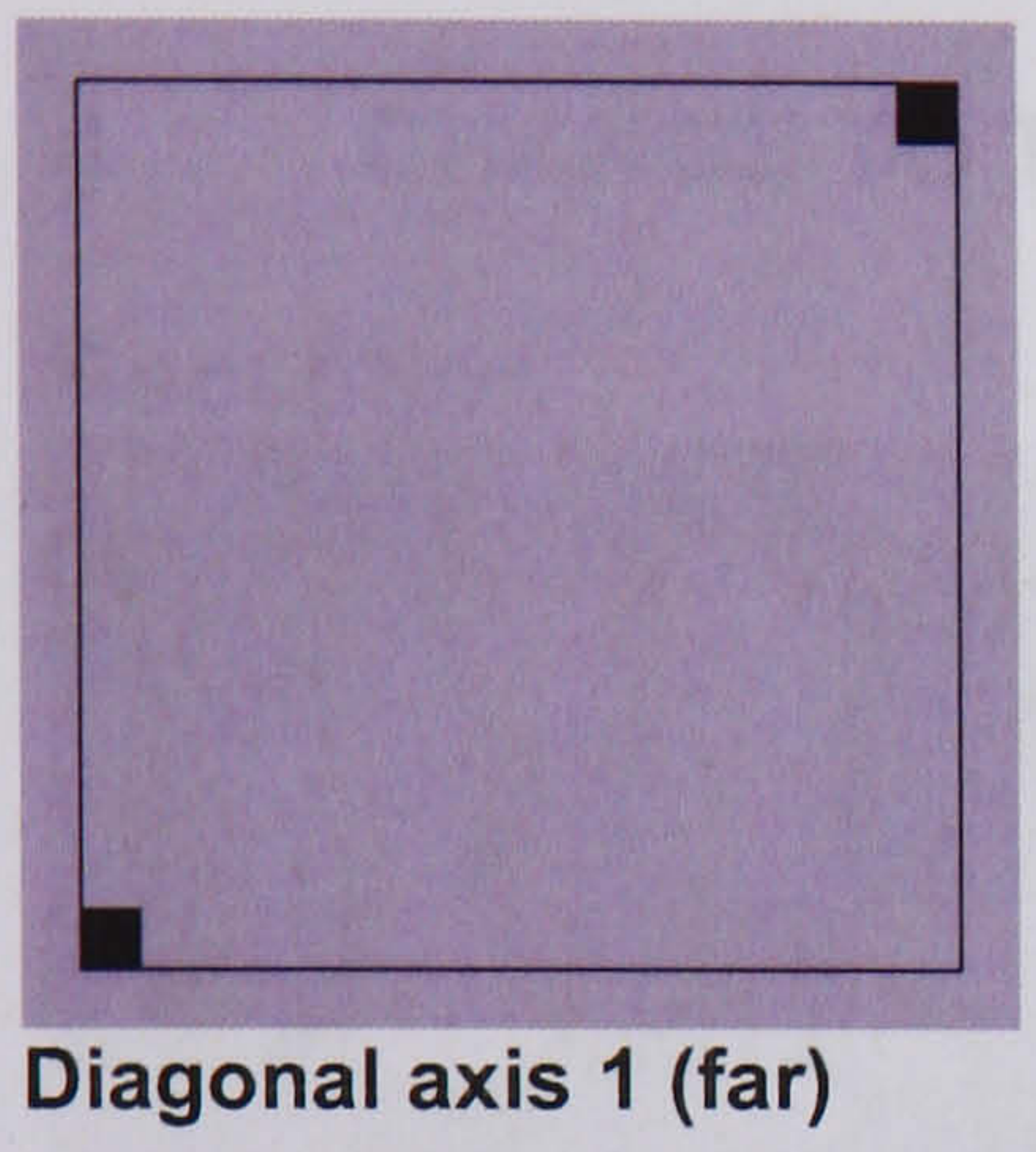
Diagonal axis 1 (near)



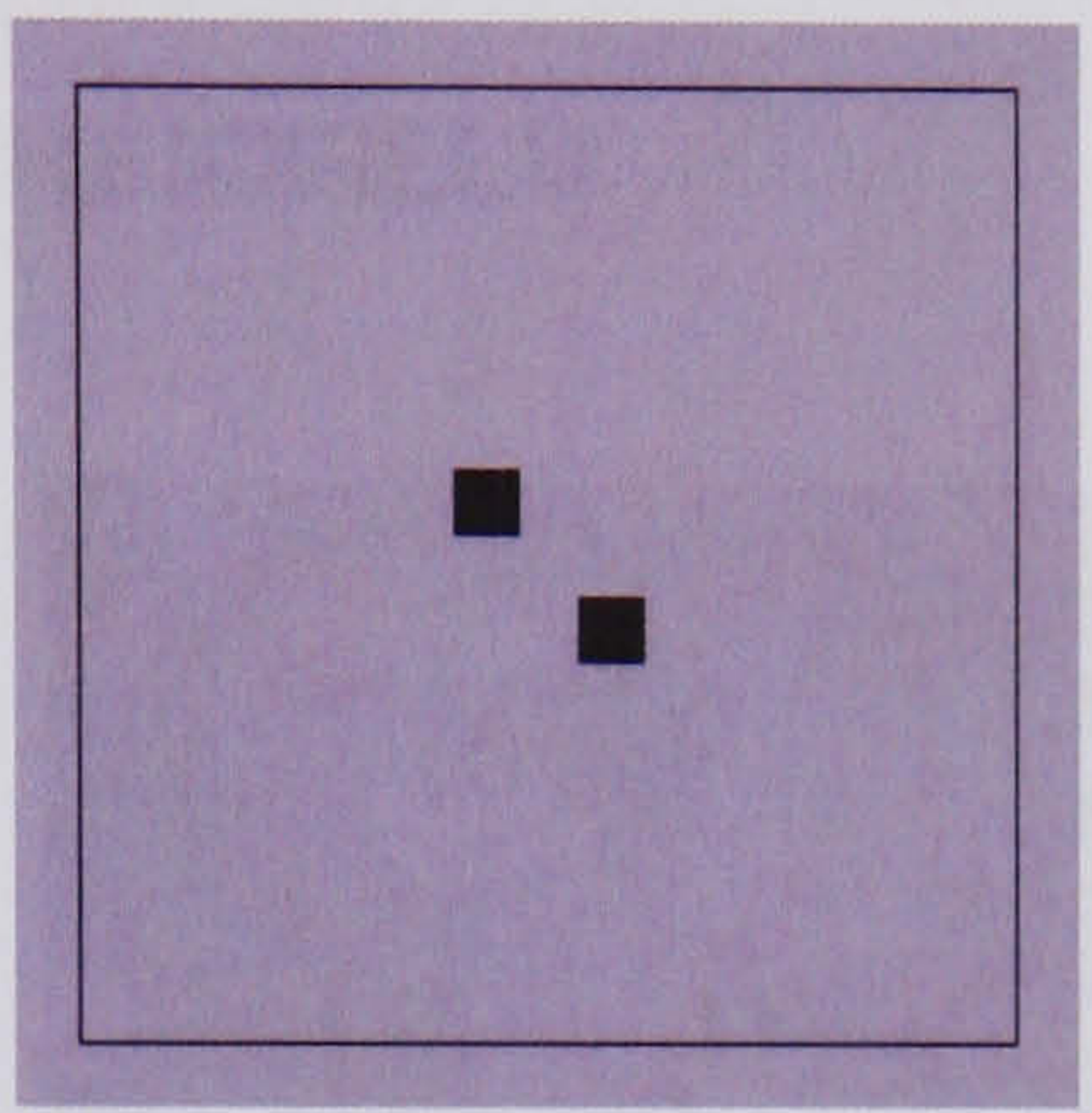
Diagonal axis 1 (Near - mid)



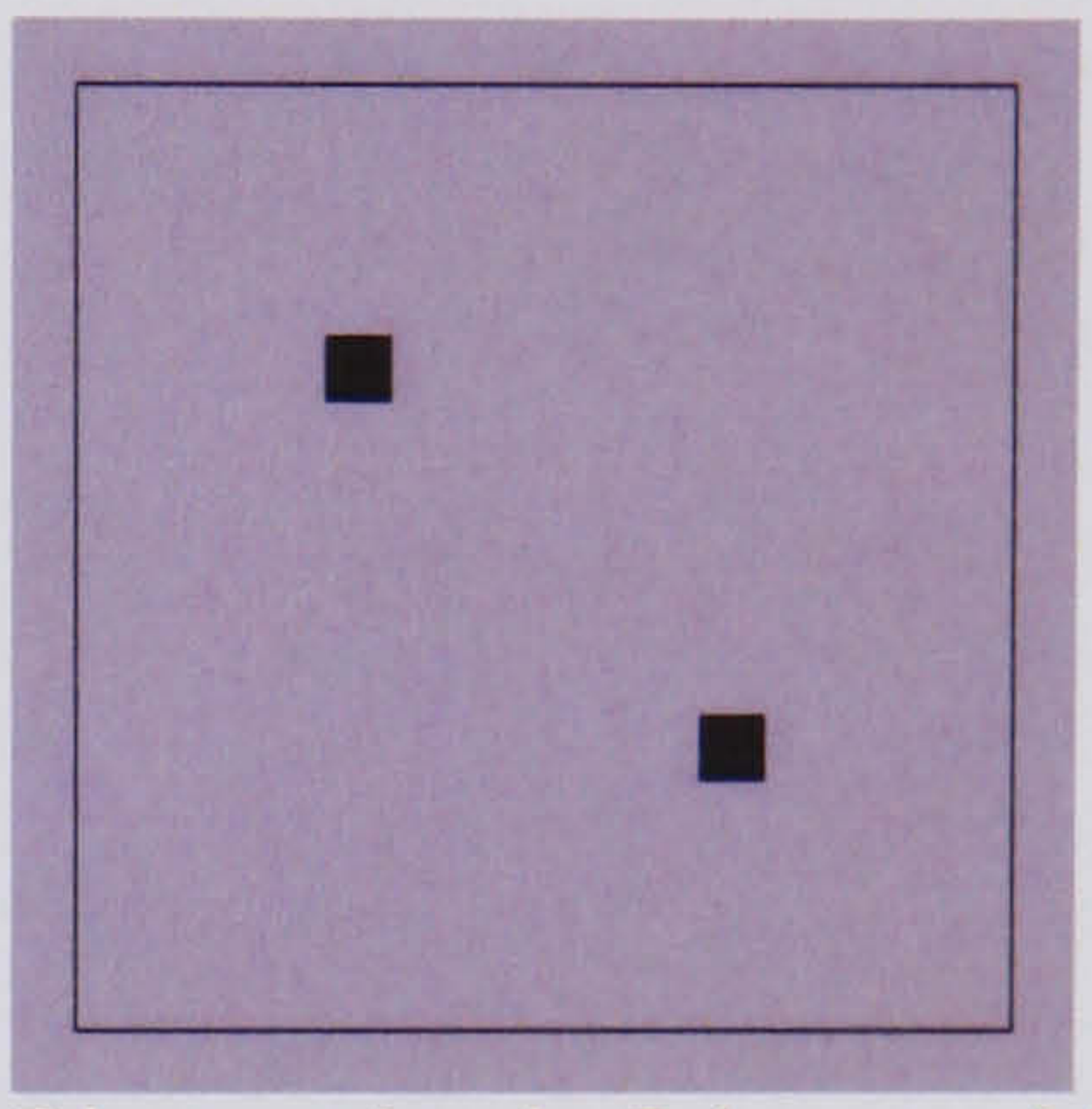
Diagonal axis 1 (mid -far)



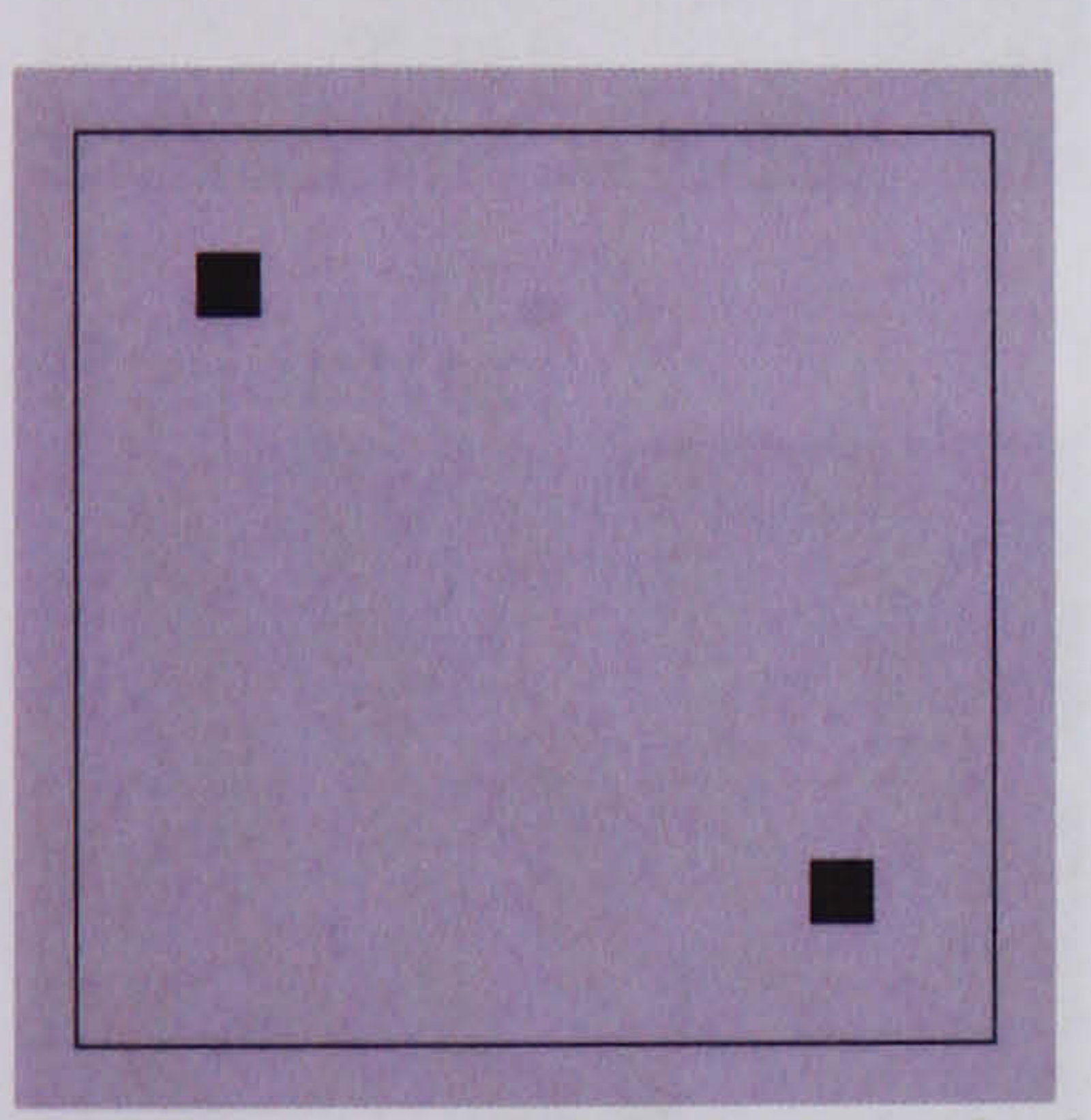
Diagonal axis 1 (far)



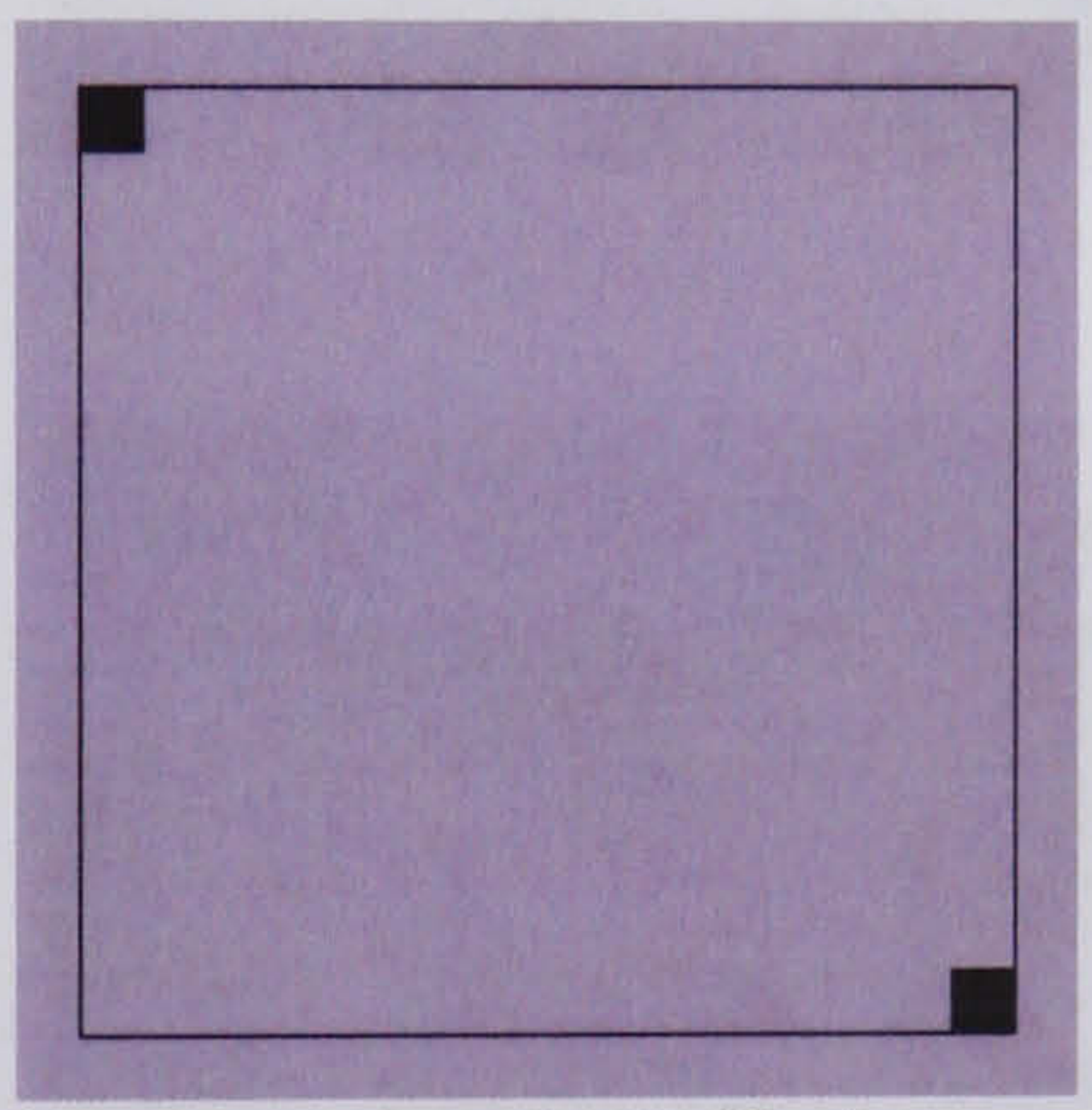
Diagonal axis 2 (near)



Diagonal axis 2 (near-mid)



Diagonal axis 2 (mid - far)



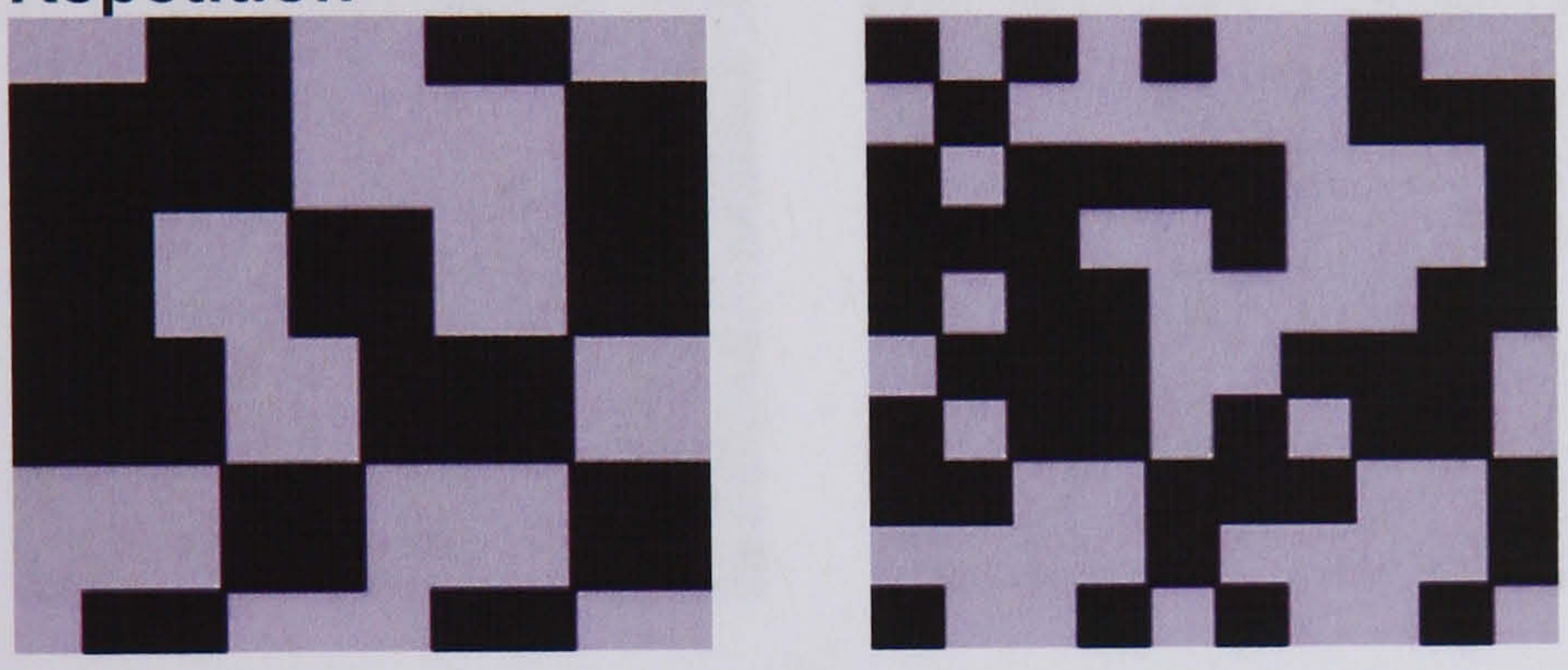
Diagonal axis 2 (far)

D) Hemifield stimuli

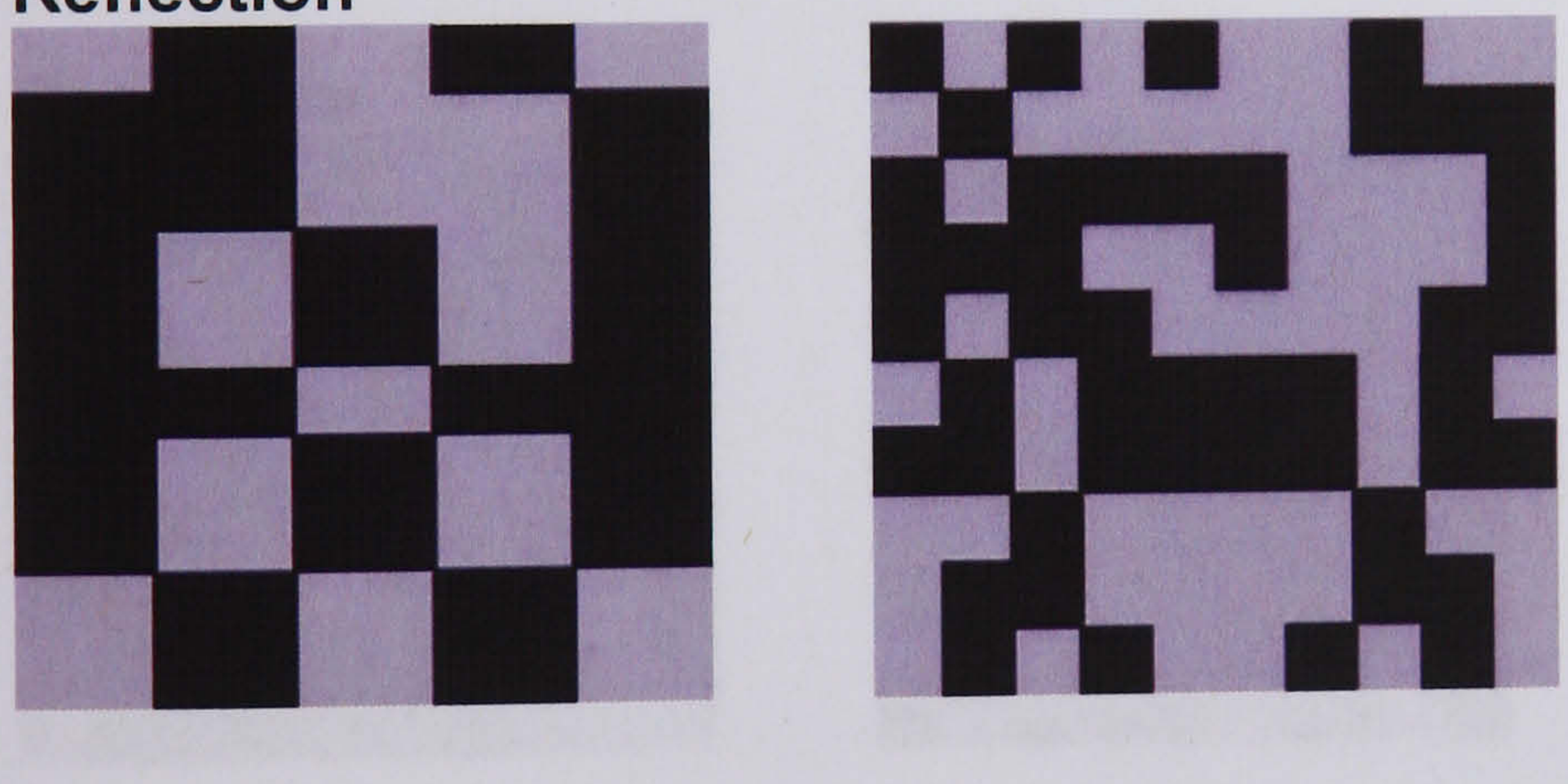
Hemifield stimuli were all based upon the basic abstract patterns (part a). In the hemifield scenario one half of the reflected or repeated patterns (either the top, bottom, left or right) is replaced by half of a random pattern. This represents the change. Below are examples of these changes for each condition.

i) CHANGE TO TOP HEMIFIELD

Repetition

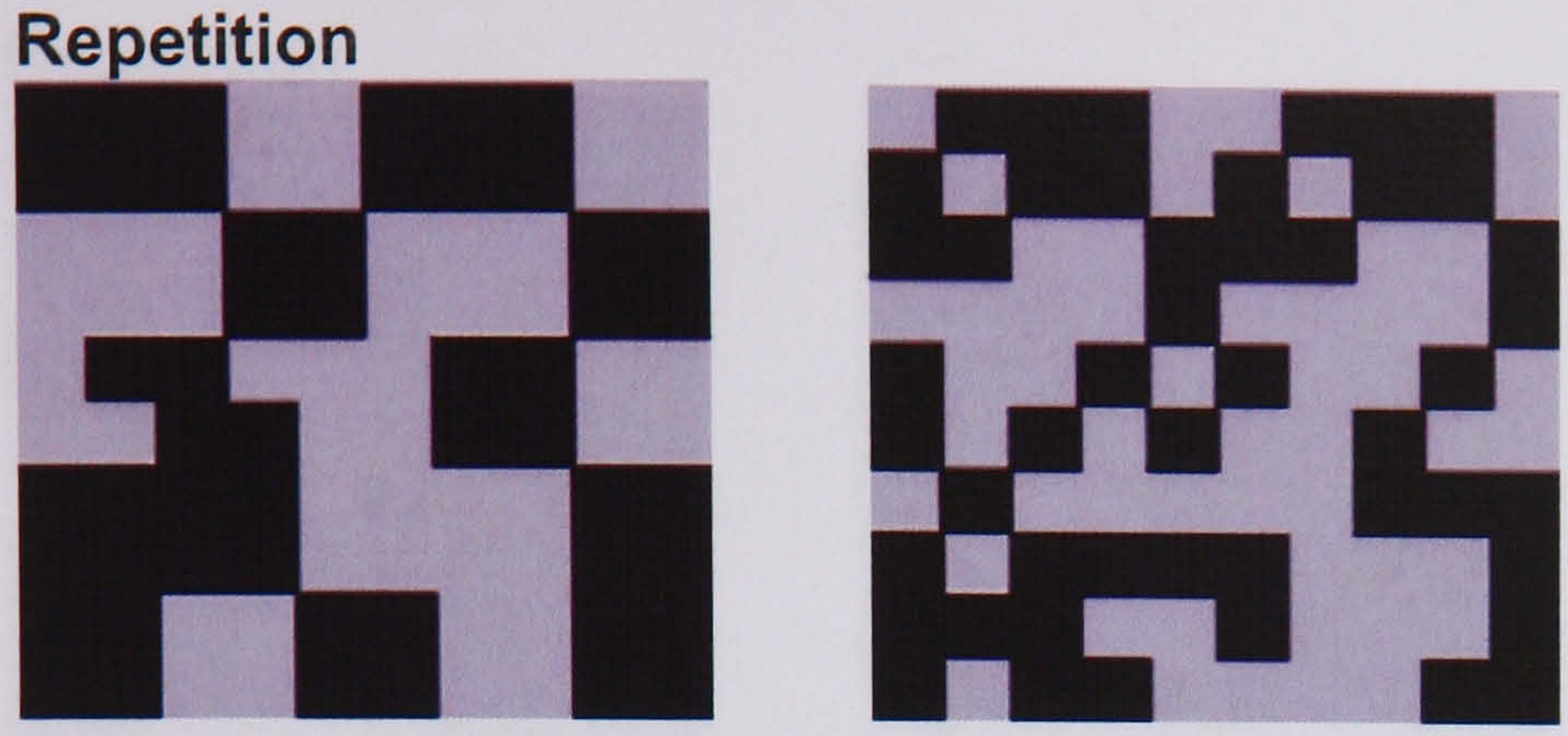


Reflection

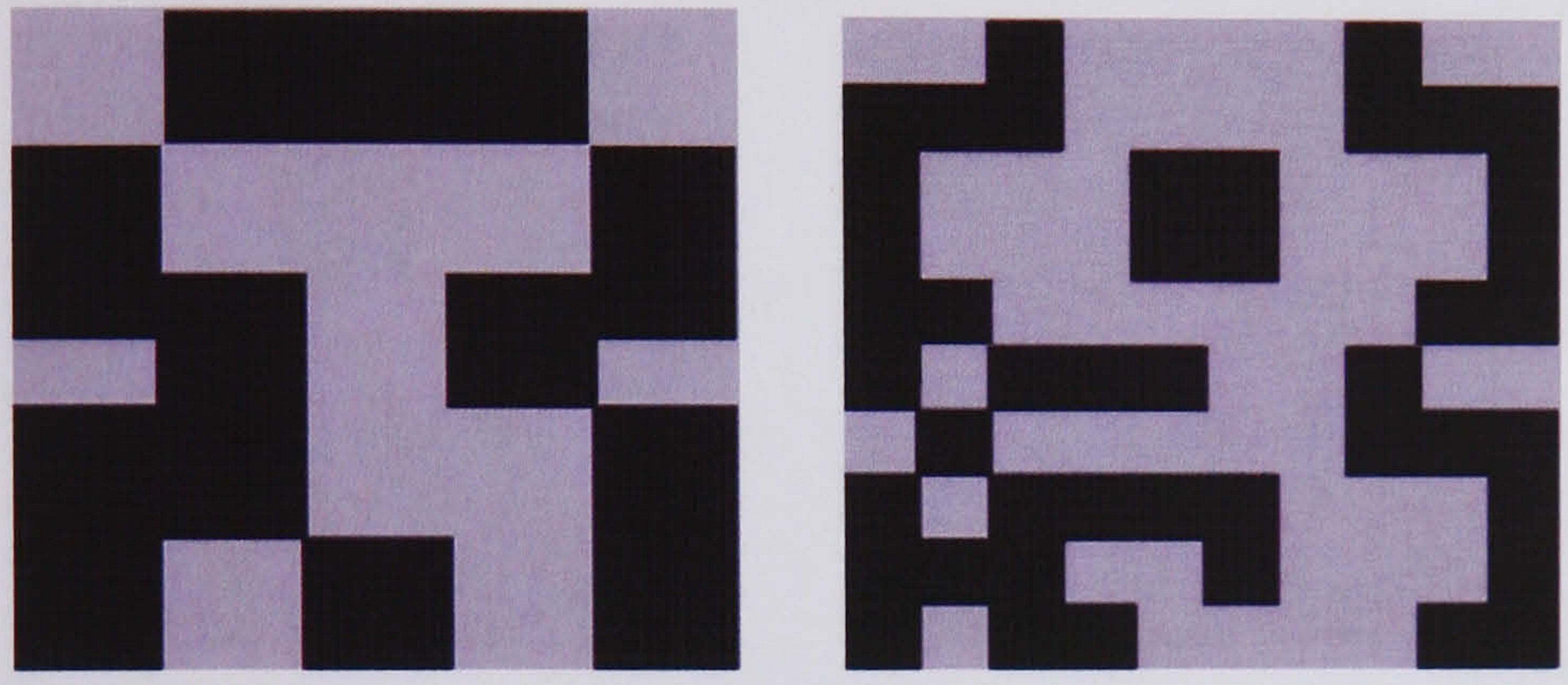


ii) CHANGE TO BOTTOM HEMIFIELD

Repetition

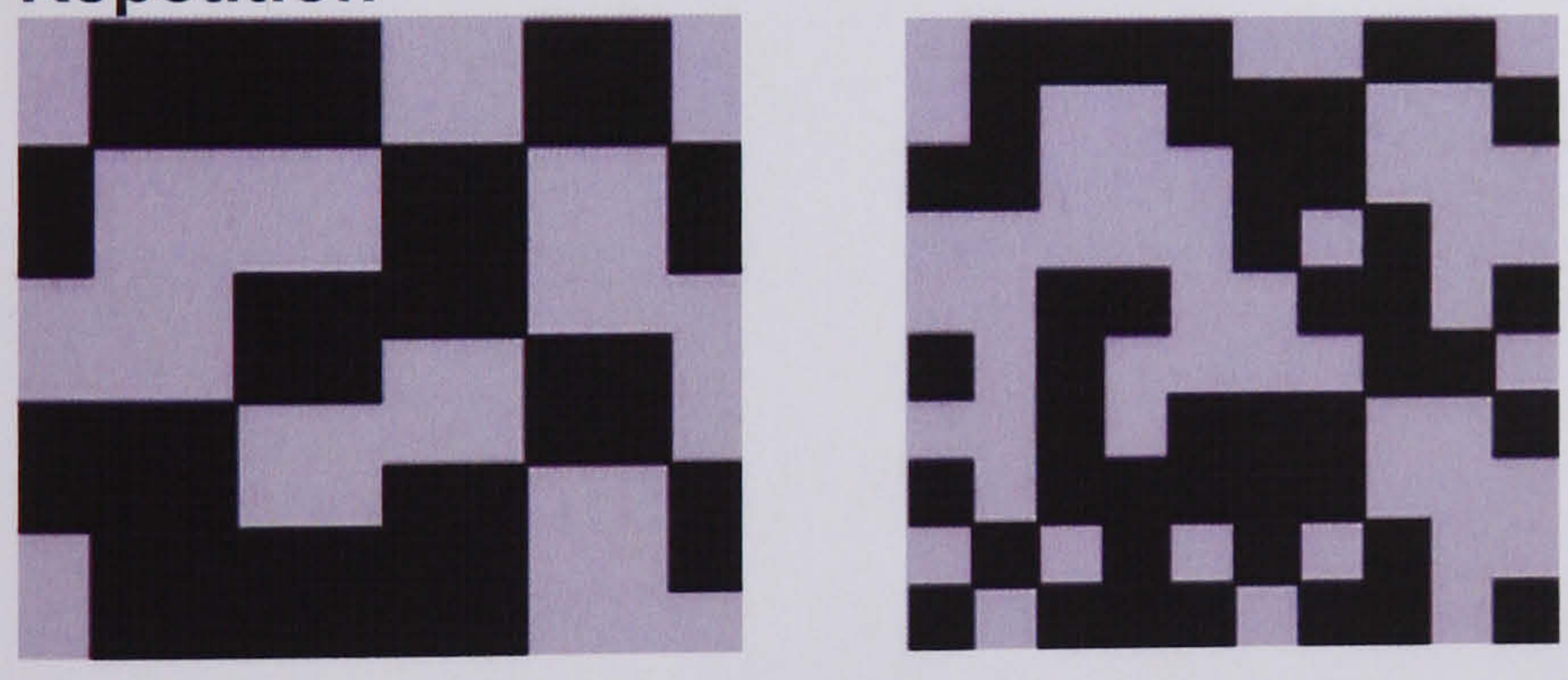


Reflection

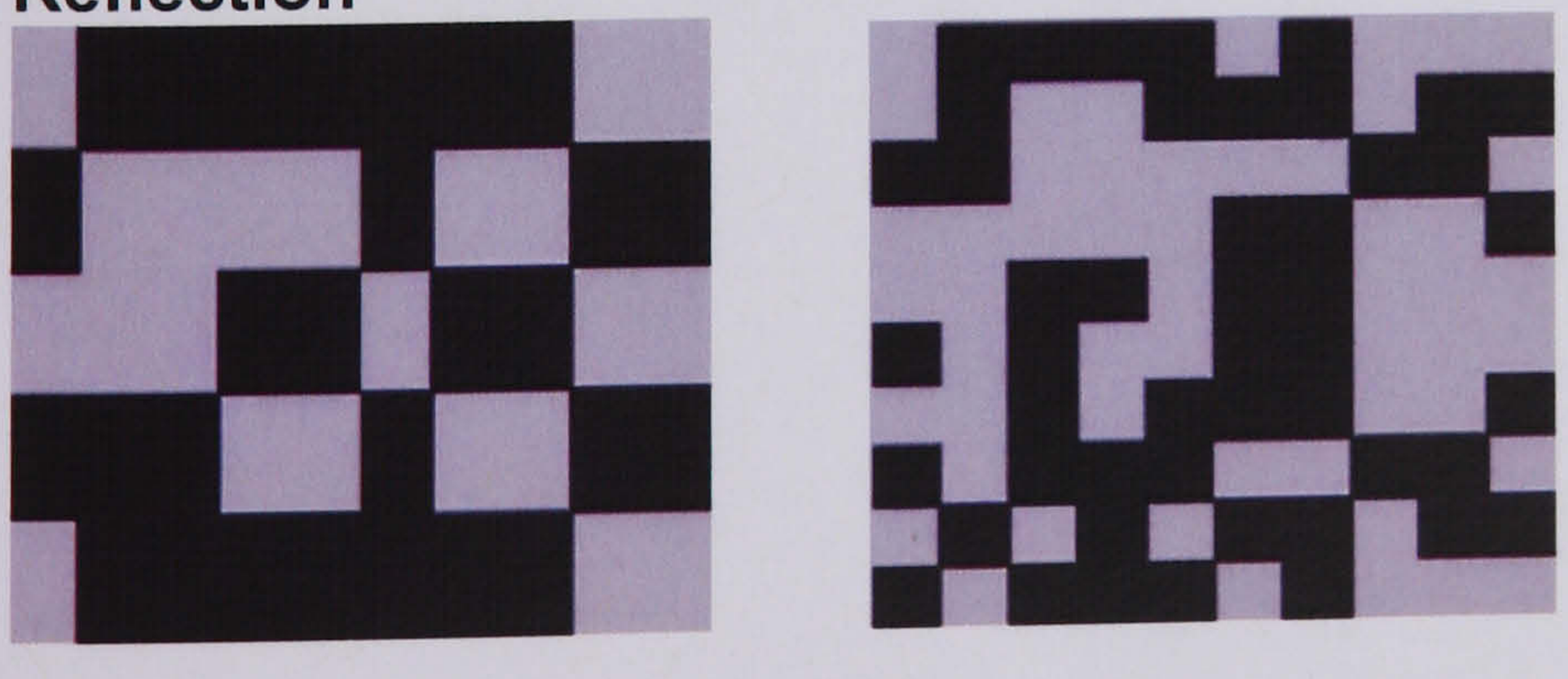


iii) CHANGE TO LEFT HEMIFIELD

Repetition

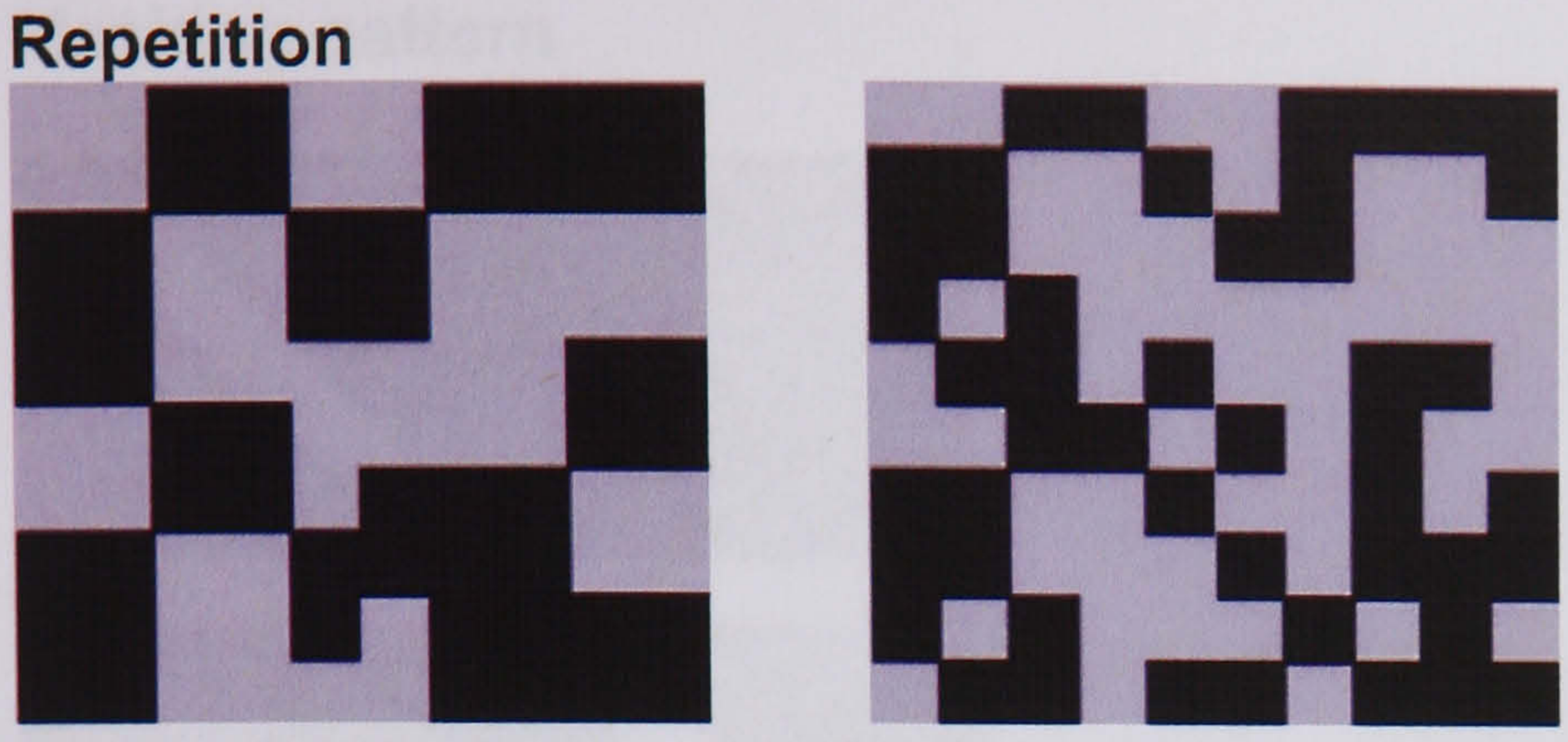


Reflection

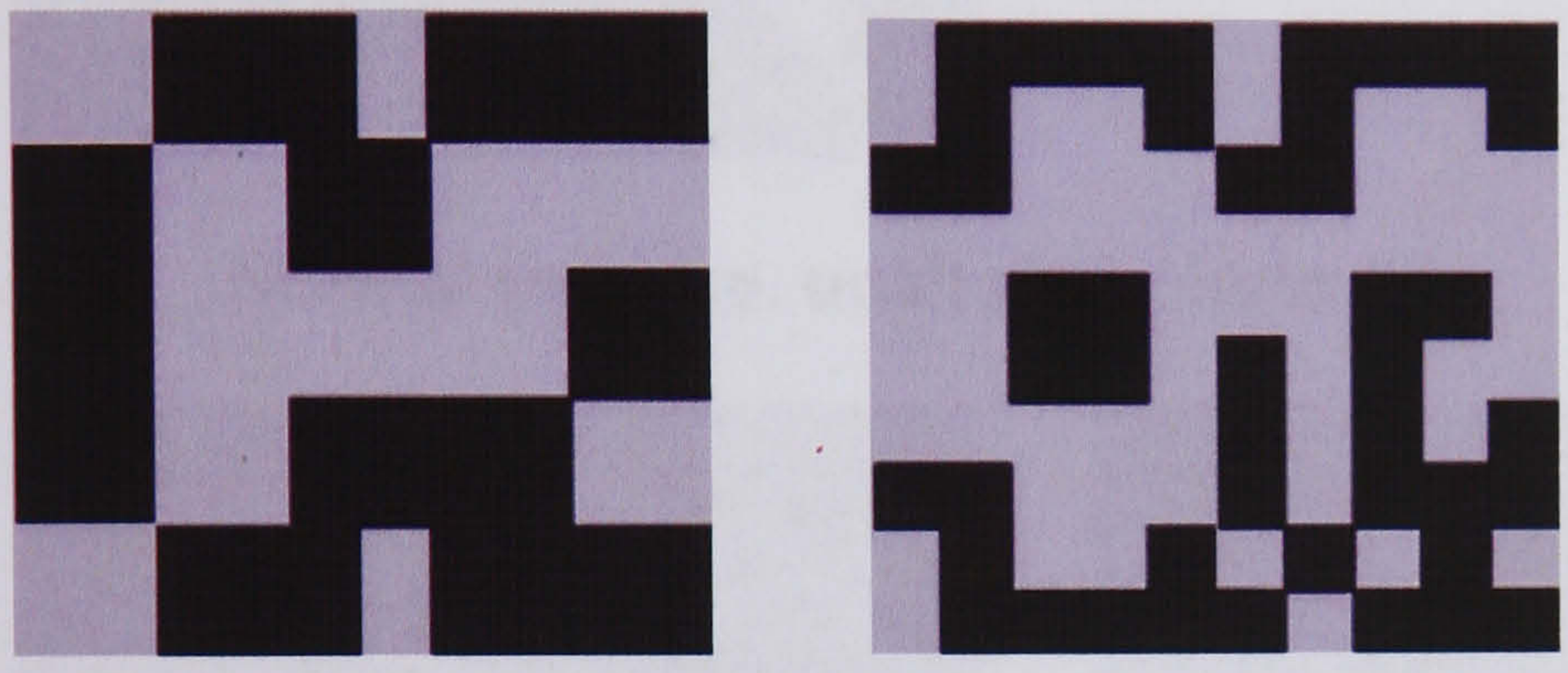


iv) CHANGE TO RIGHT HEMIFIELD

Repetition



Reflection



E) FACIAL STIMULI

Masking pattern

i) Normal face (i.e. unaltered photo fit)

ii) Eyes removed condition

iii) Mouth removed condition

iv) Normal face no nose

v) Reduced eye-contrast condition (sclera and iris contrast reduced by 70% from normal)

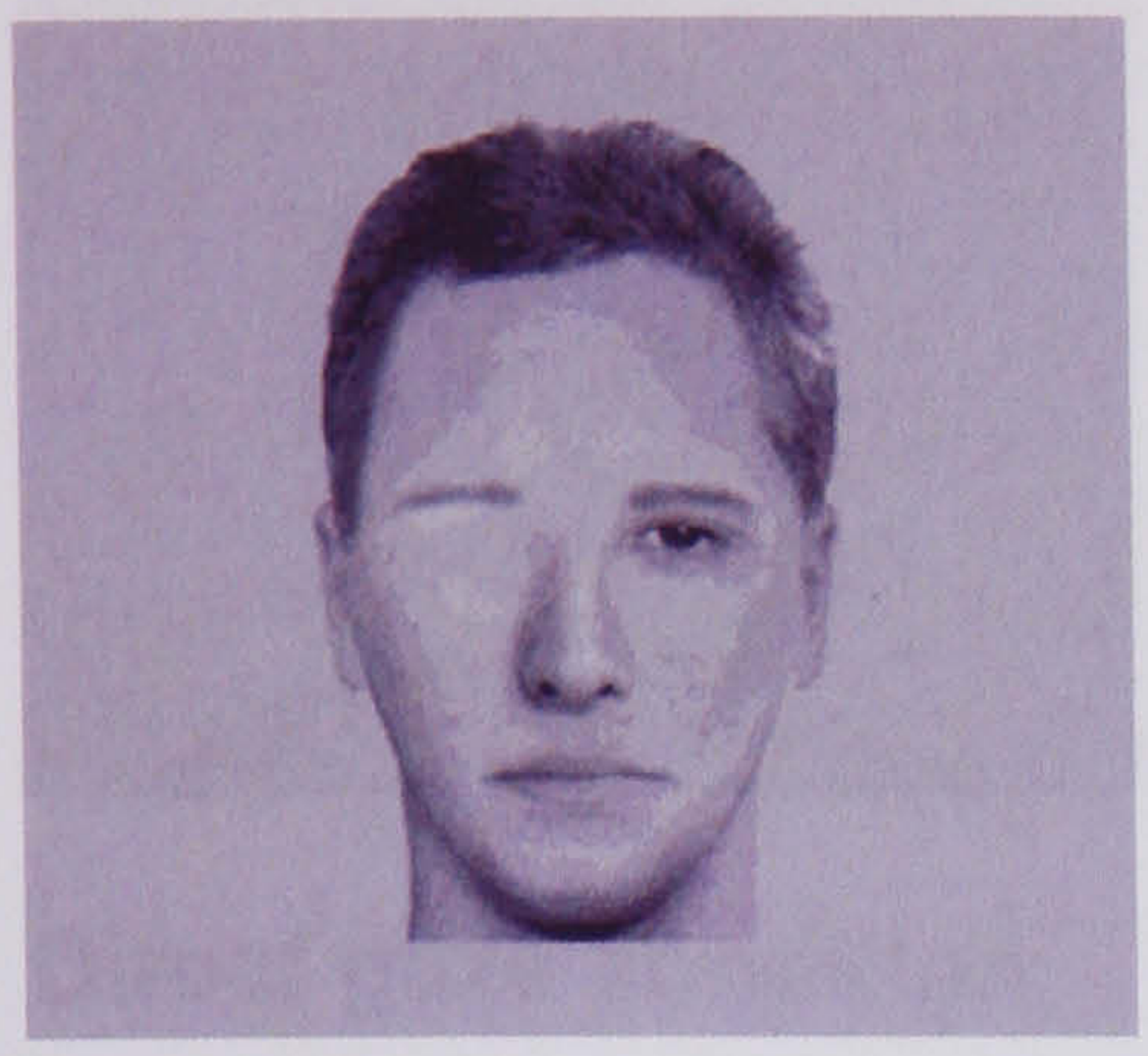
vi) Standard distorted face

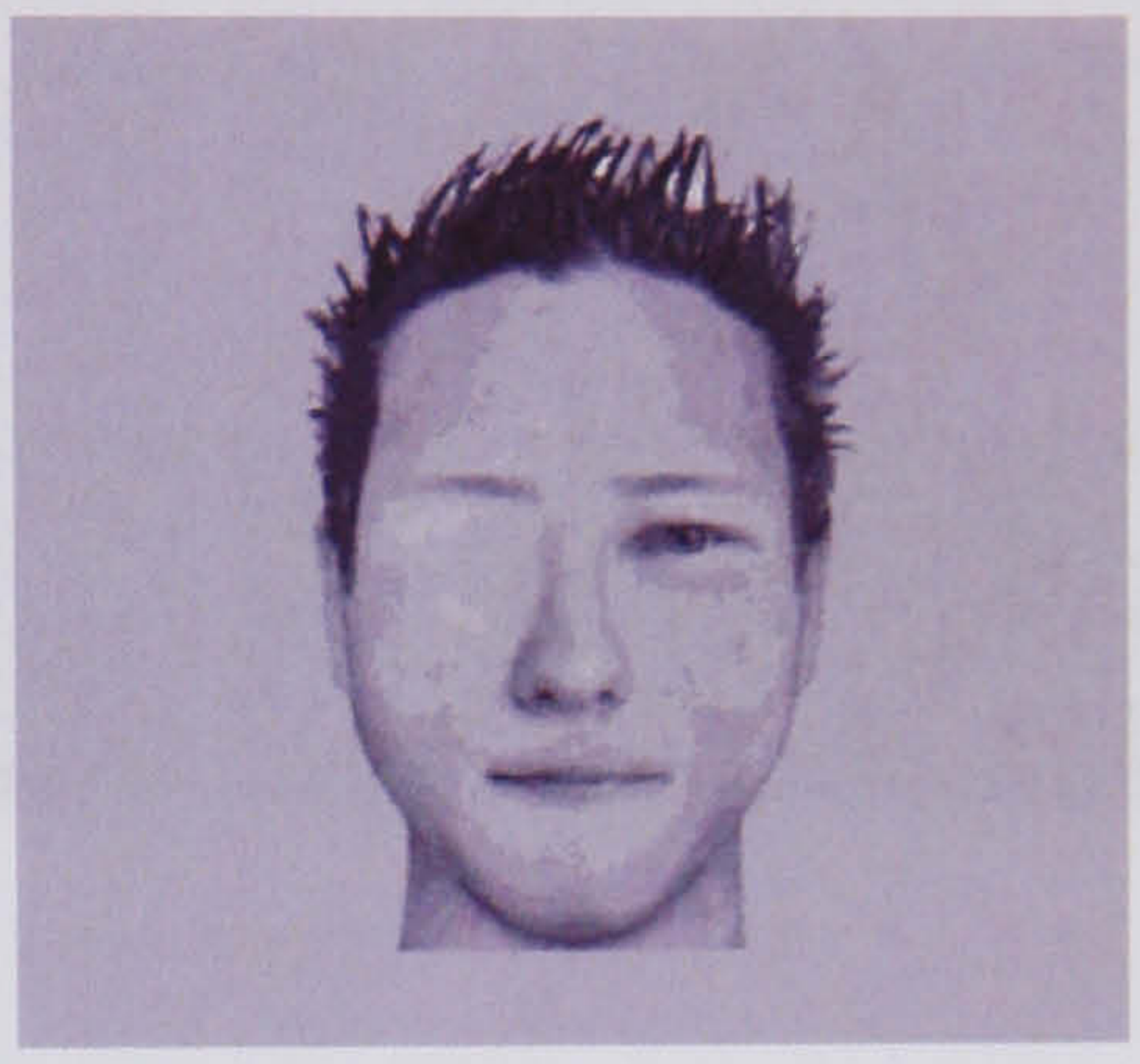
vi) Distorted face no eyes

vii) Distorted face no mouth

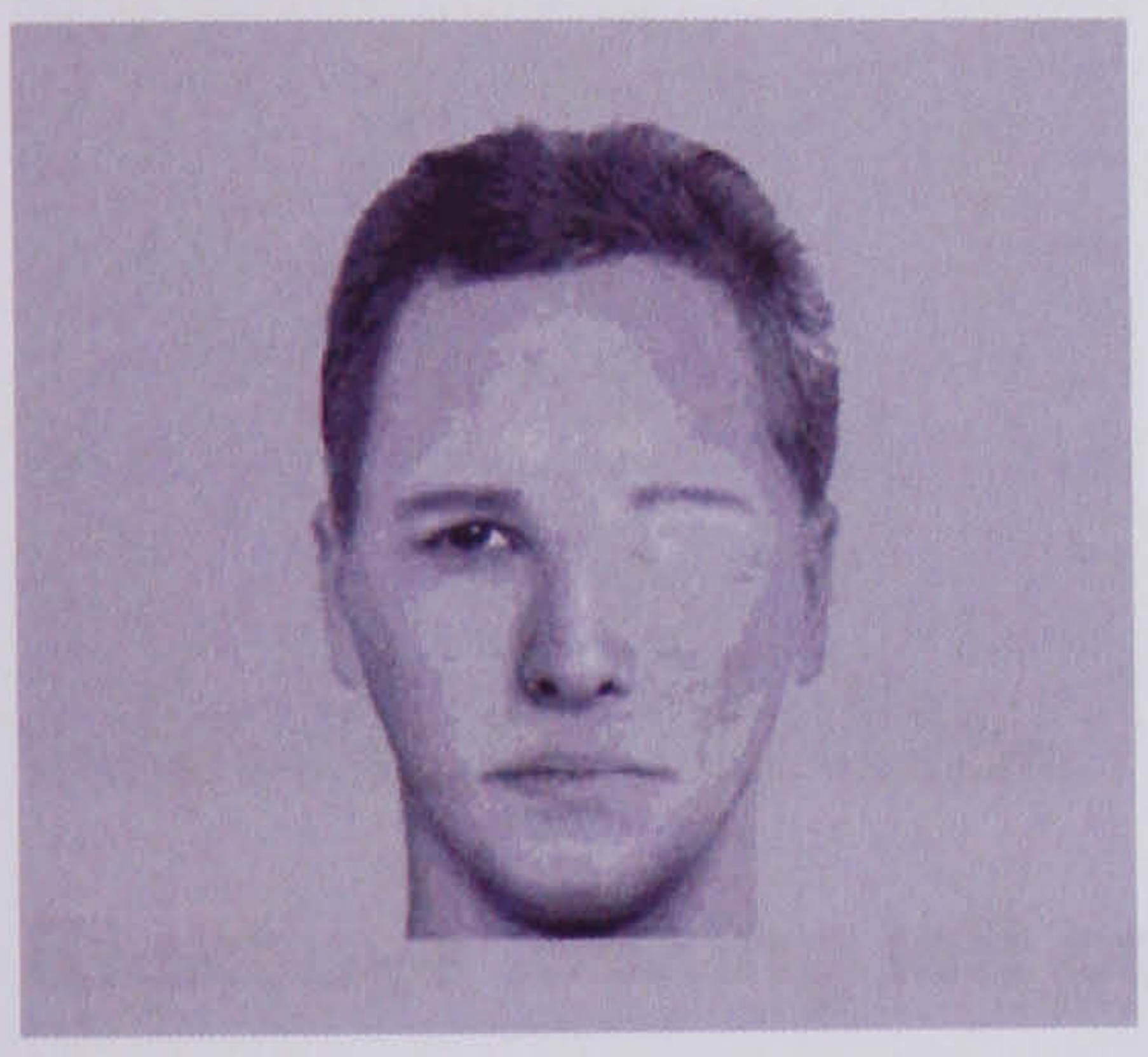
F) Hemispheric face experiment

i) Left eye missing condition





ii) Right eye missing condition



G) Eye-gaze direction stimuli

Normal contrast 50% contrast 70% contrast

Direct gaze condition

Normal contrast 50% contrast 70% contrast

Right eye looking left condition

Normal contrast 50% contrast 70% contrast

Right eye looking right condition

Normal contrast 50% contrast 70% contrast

Left eye looking left condition

Normal contrast 50% contrast 70% contrast

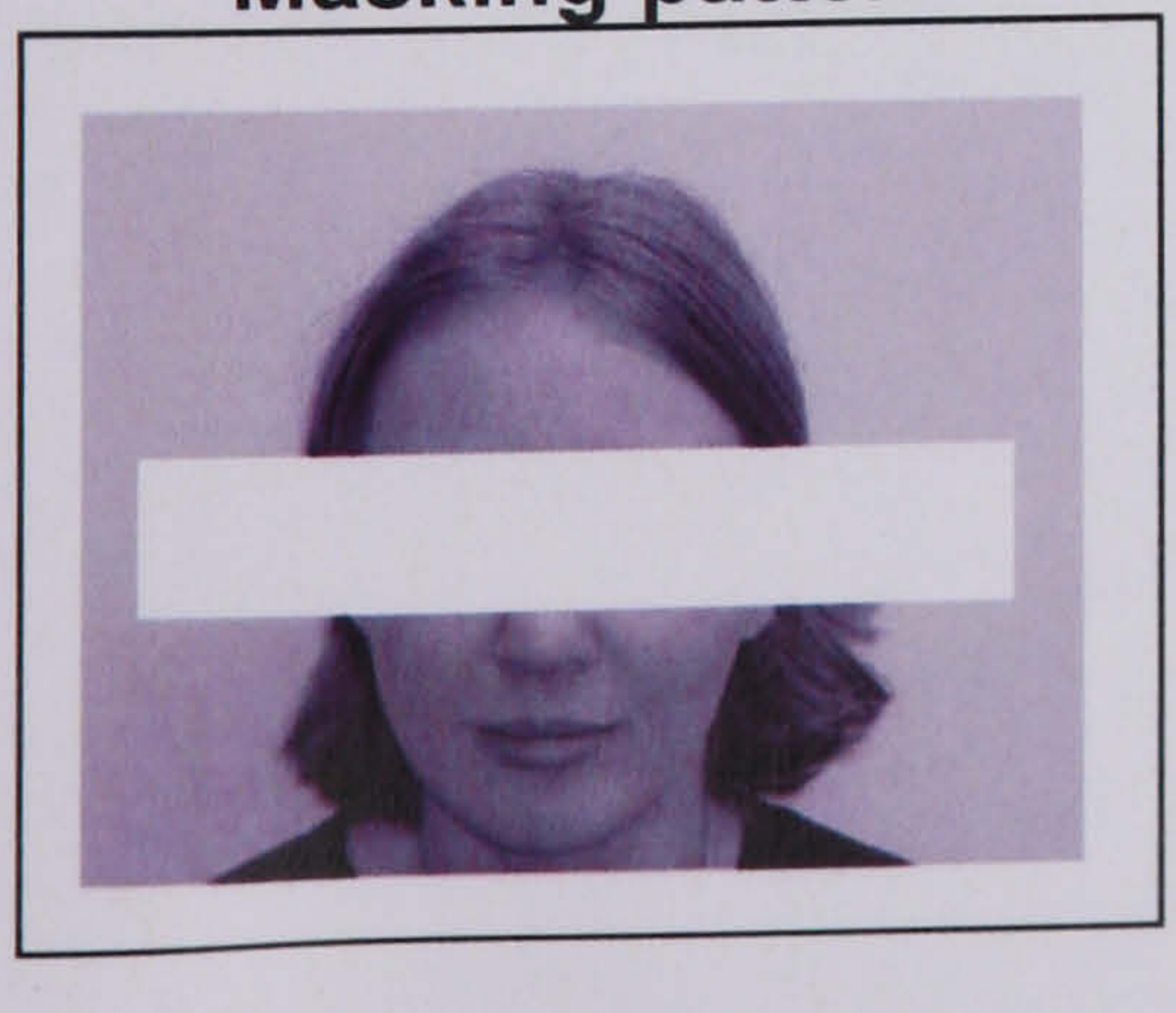
Left eye looking right condition

Normal contrast 50% contrast 70% contrast

Both eyes looking left condition

Normal contrast 50% contrast 70% contrast

Masking pattern



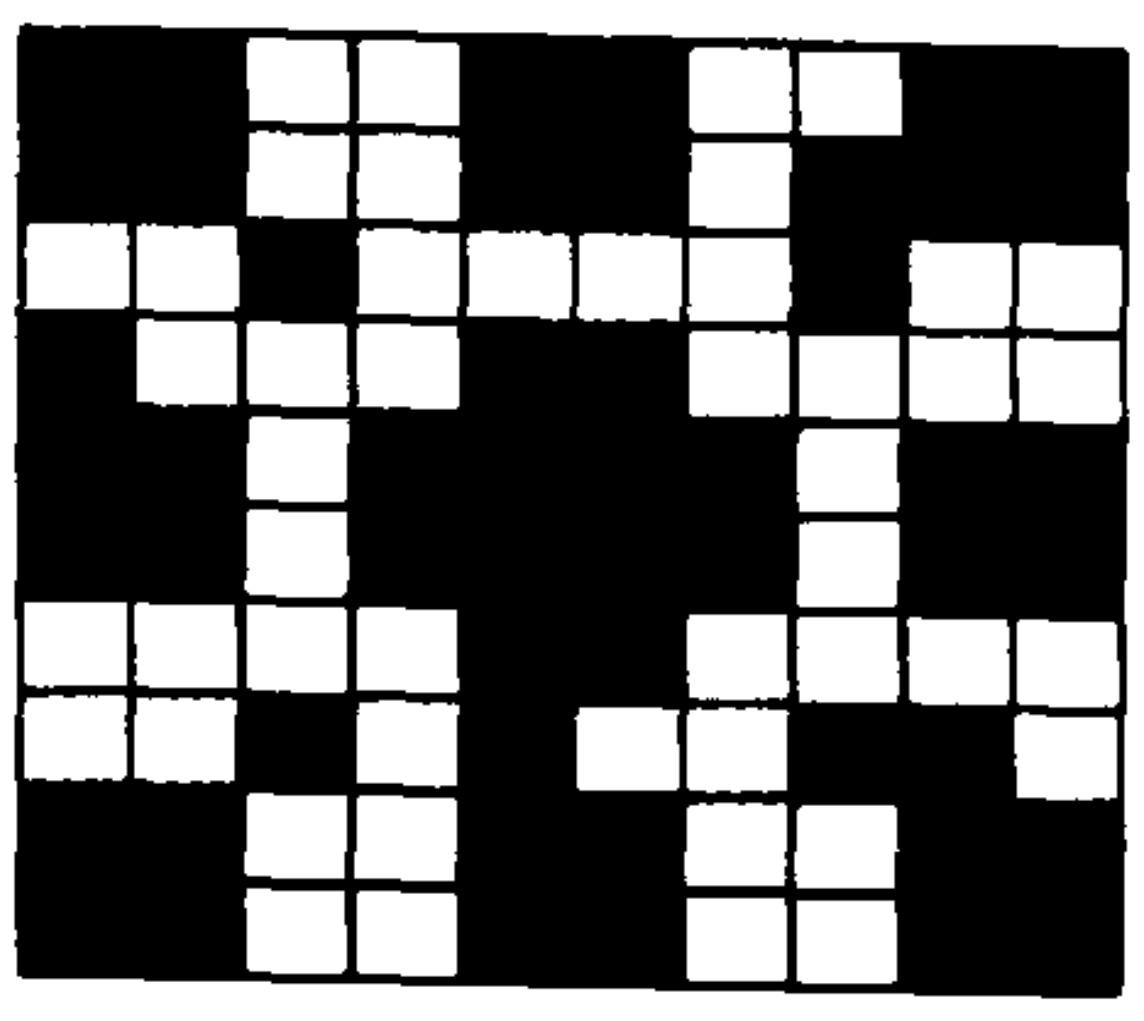
Appendix B

Pilot Study Questionnaires

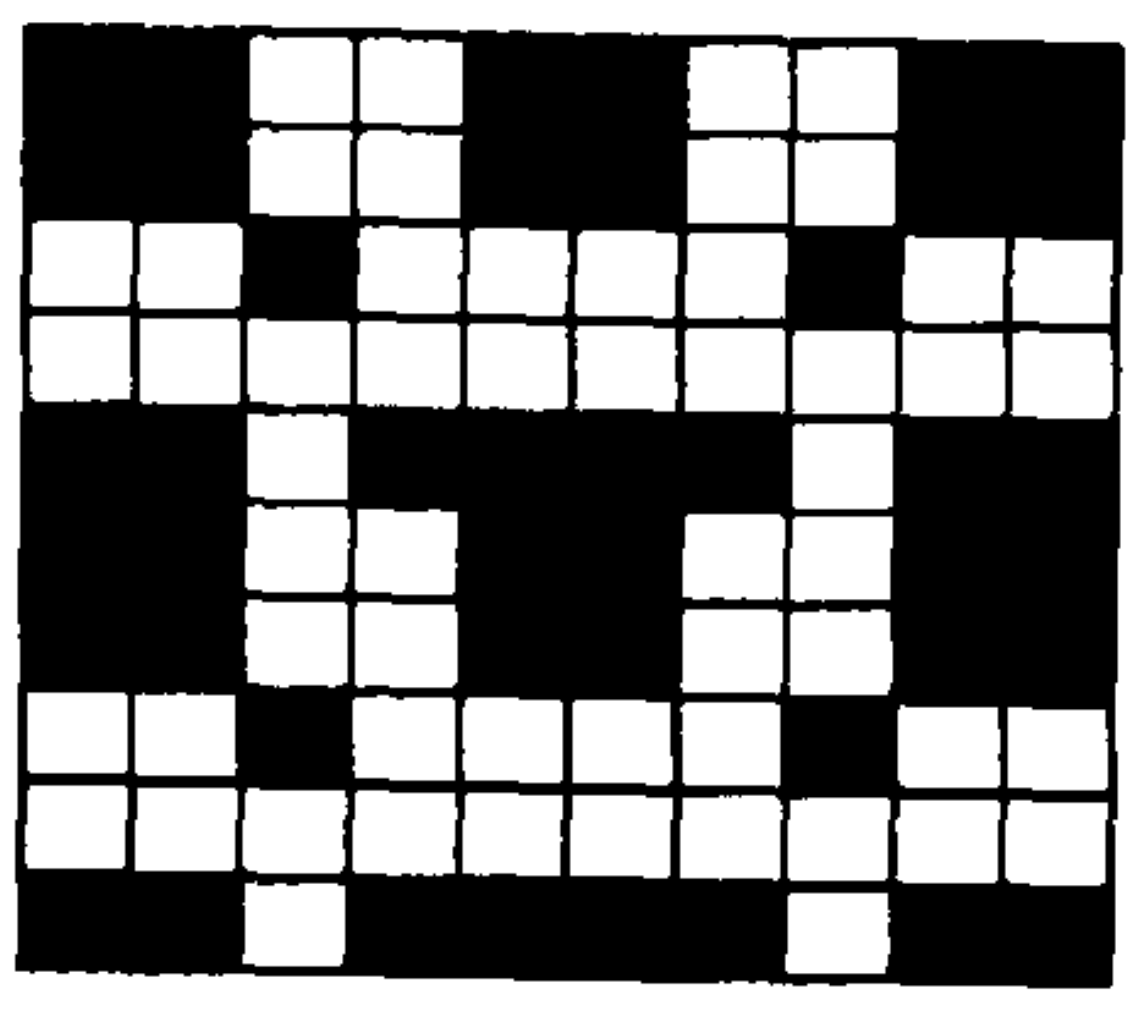
Pattern pilot study: Questionnaire 1

WHAT IS A PATTERN?

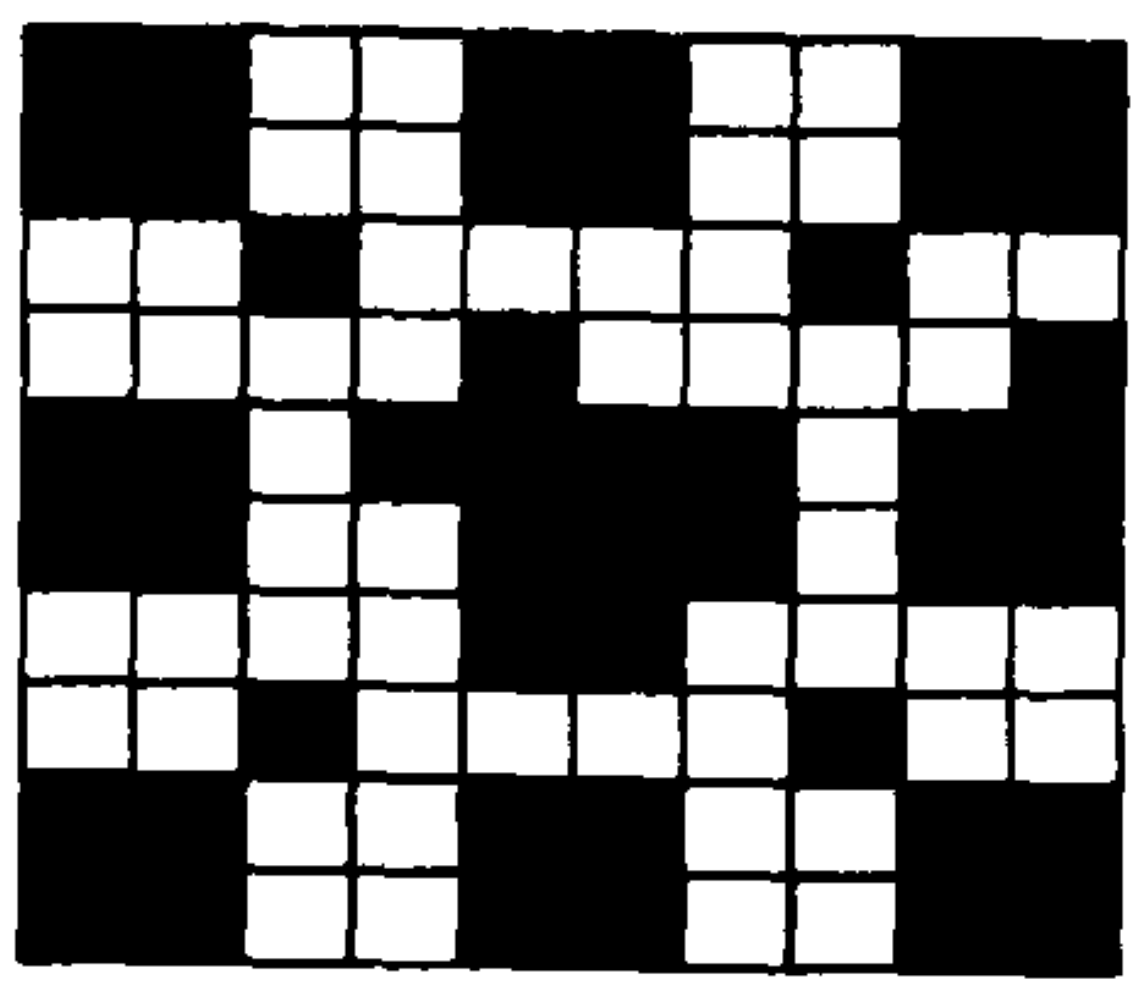
1) Please rate the pictures below according to how much each picture resembles your view of what a pattern is. (*Where 5 = most pattern like; and 1 = least pattern like)*



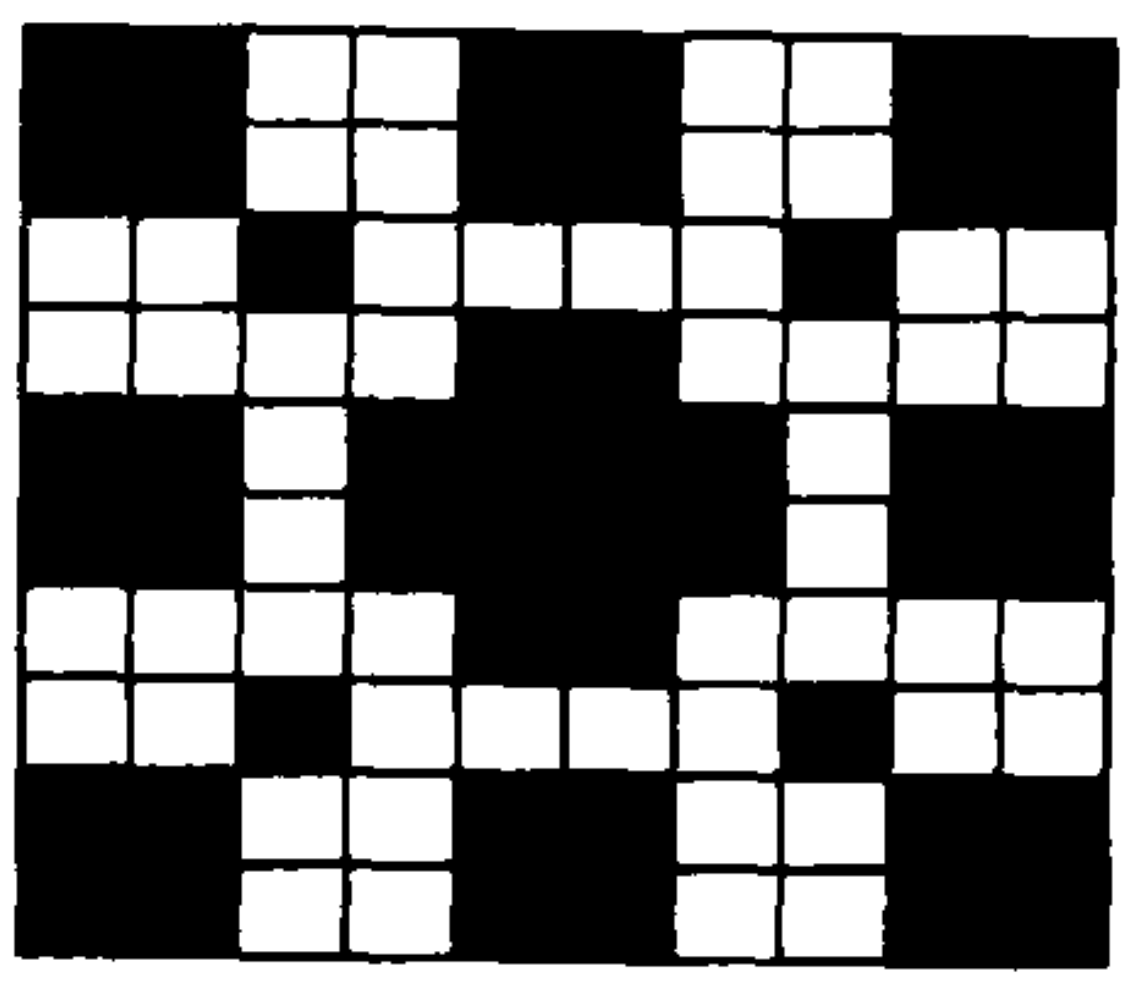
A ☐



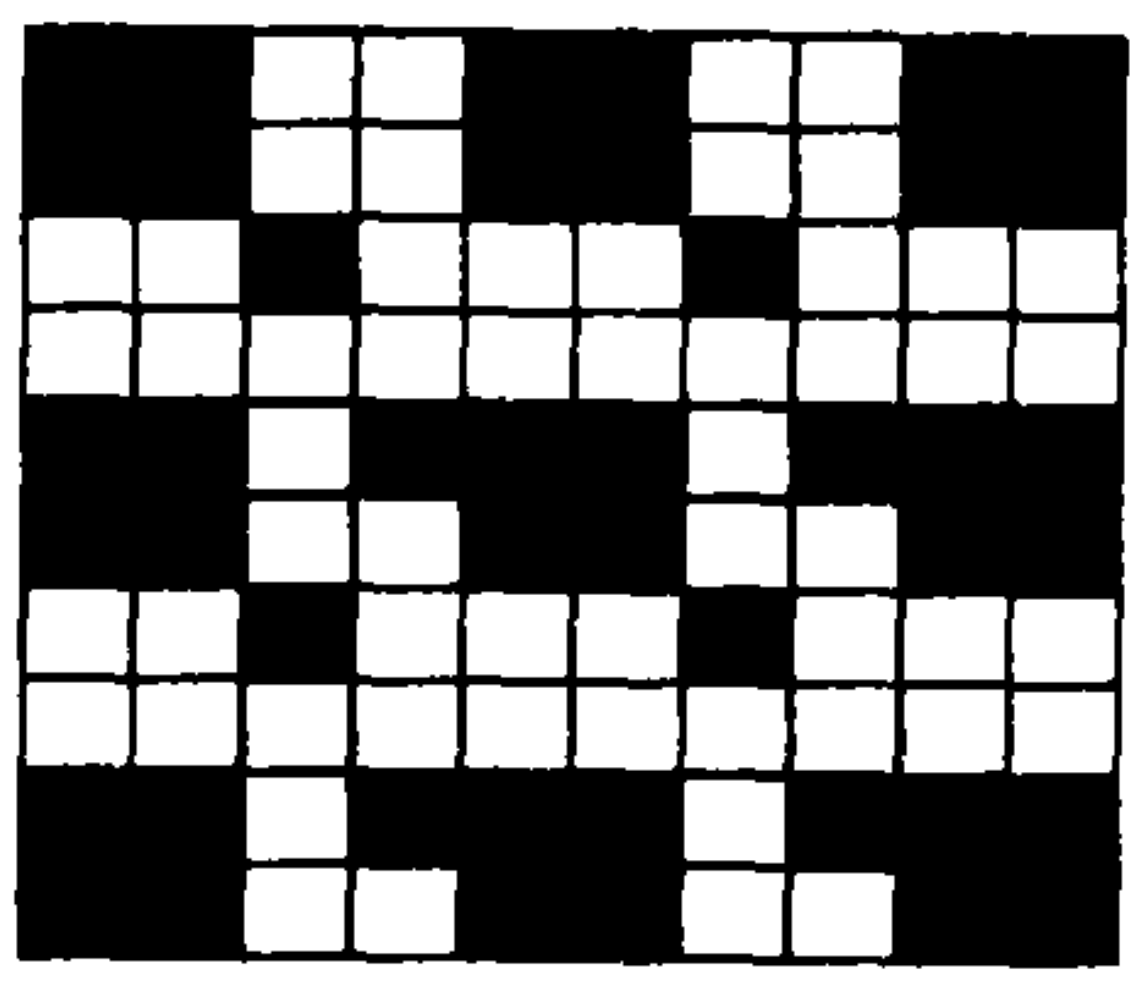
B ☐



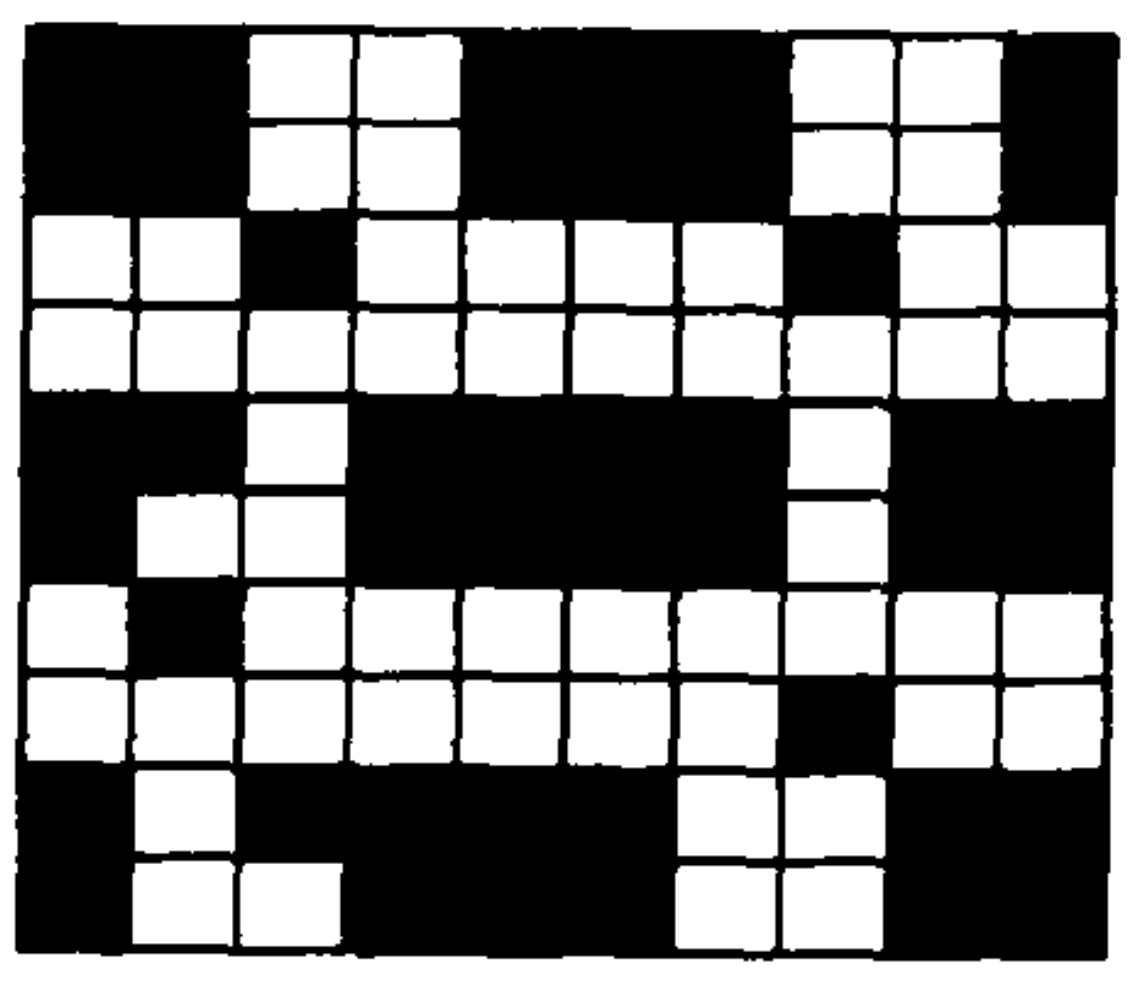
C ☐



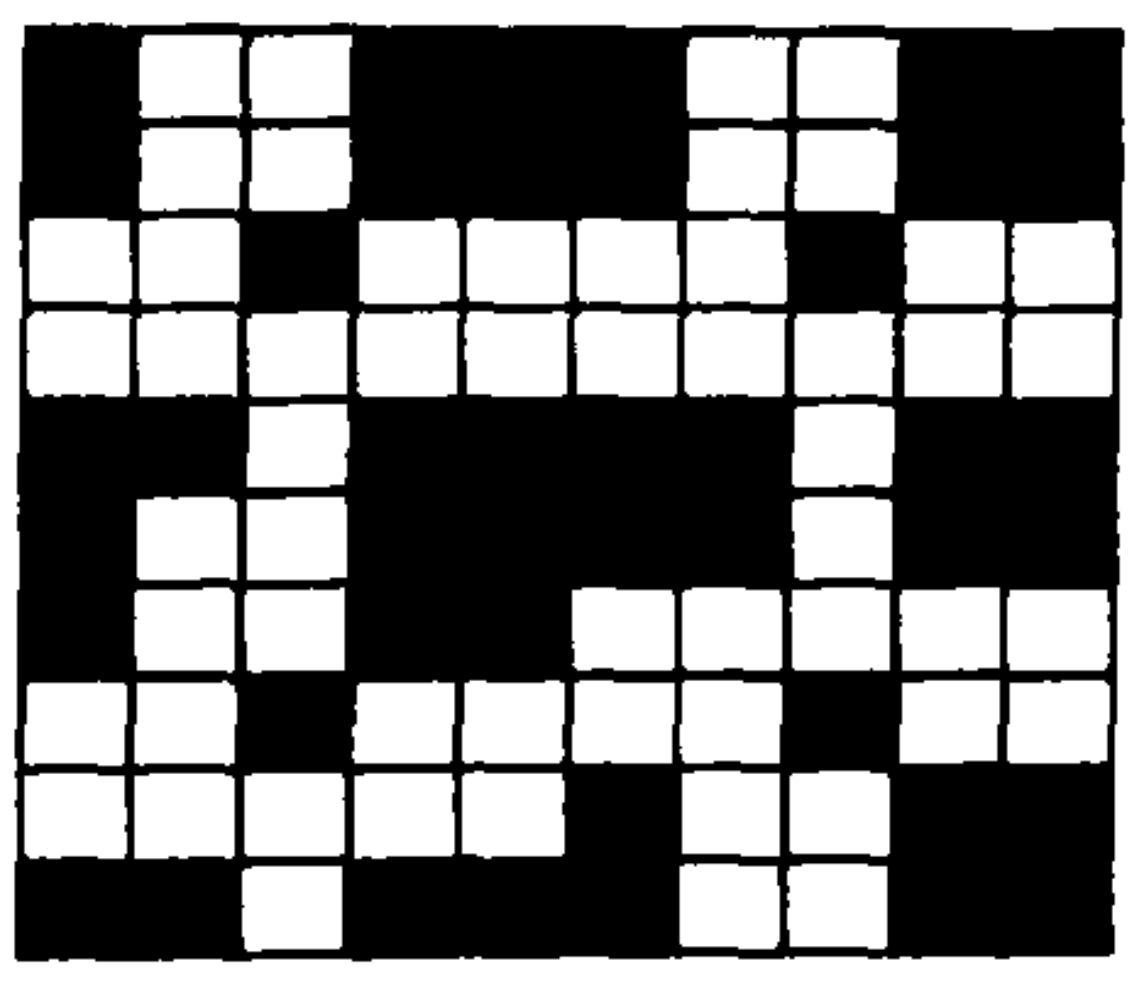
D ☐



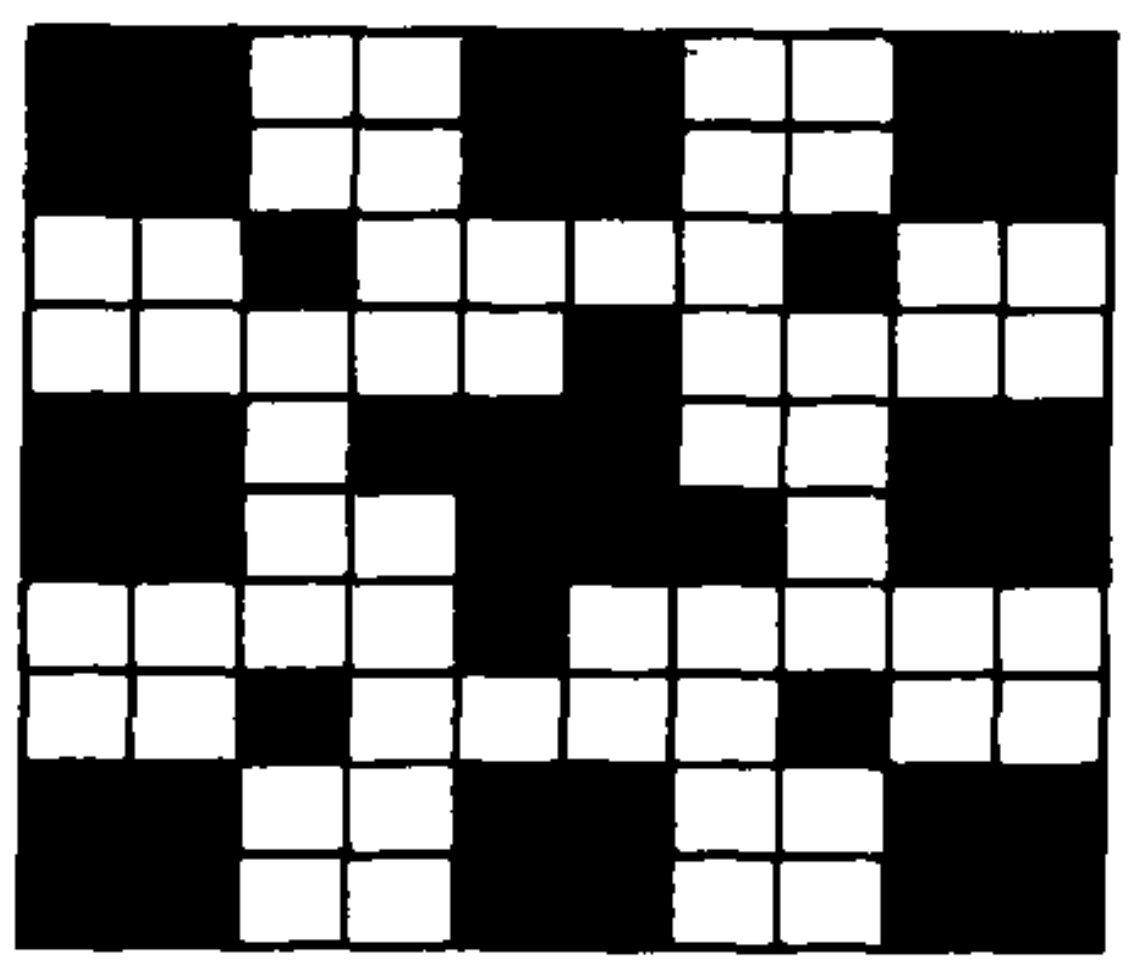
E ☐



F ☐



G ☐



H ☐

2) Which of the following terms is most important when describing what a pattern is? *Please put a tick by the most appropriate answer(s)*

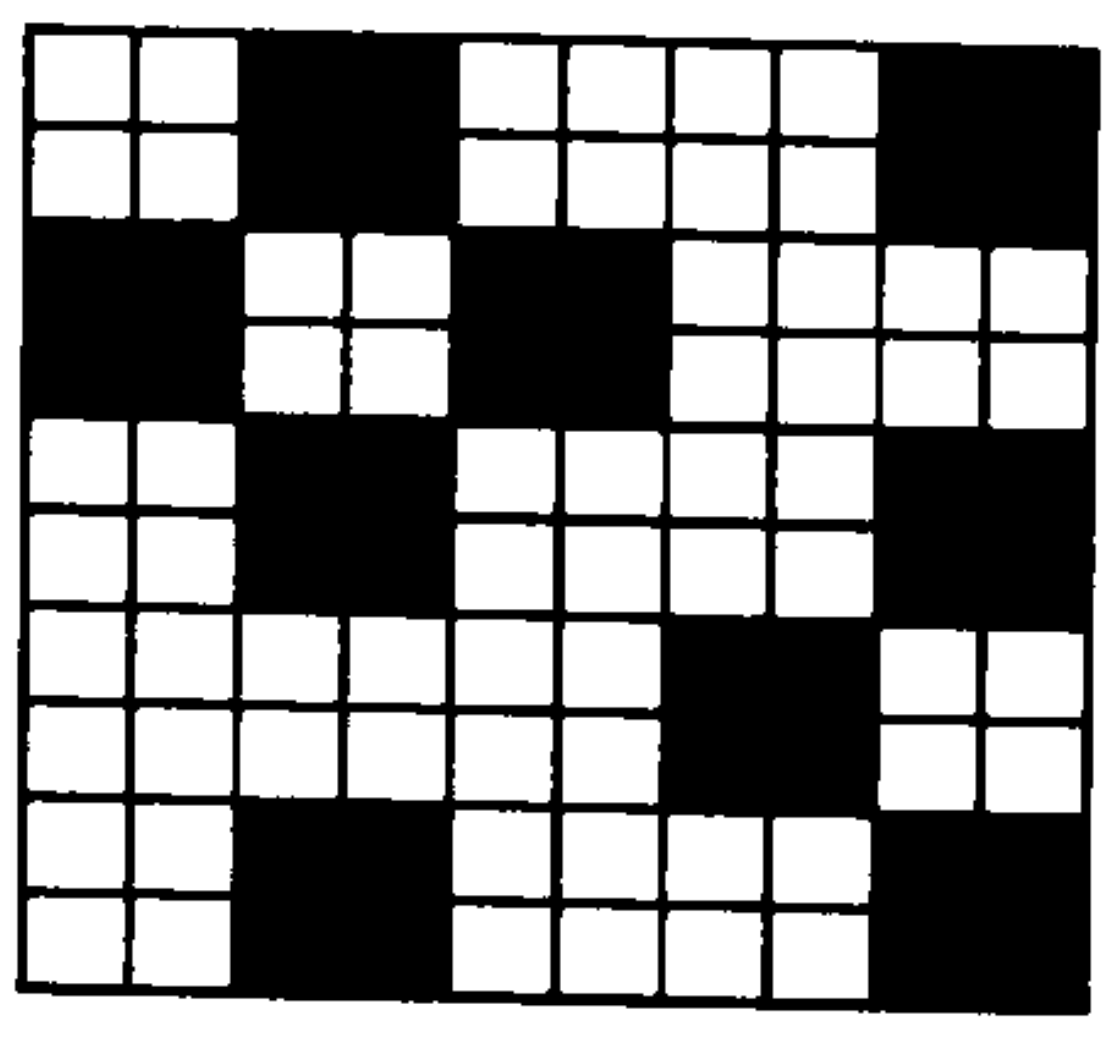
- Symmetry (e.g. rotation, repetition or reflection) ☐
- Repetition ☐
- Reflection ☐
- Novelty ☐
- Pleasing to the eye ☐
- Complexity ☐
- Other (please specify)..

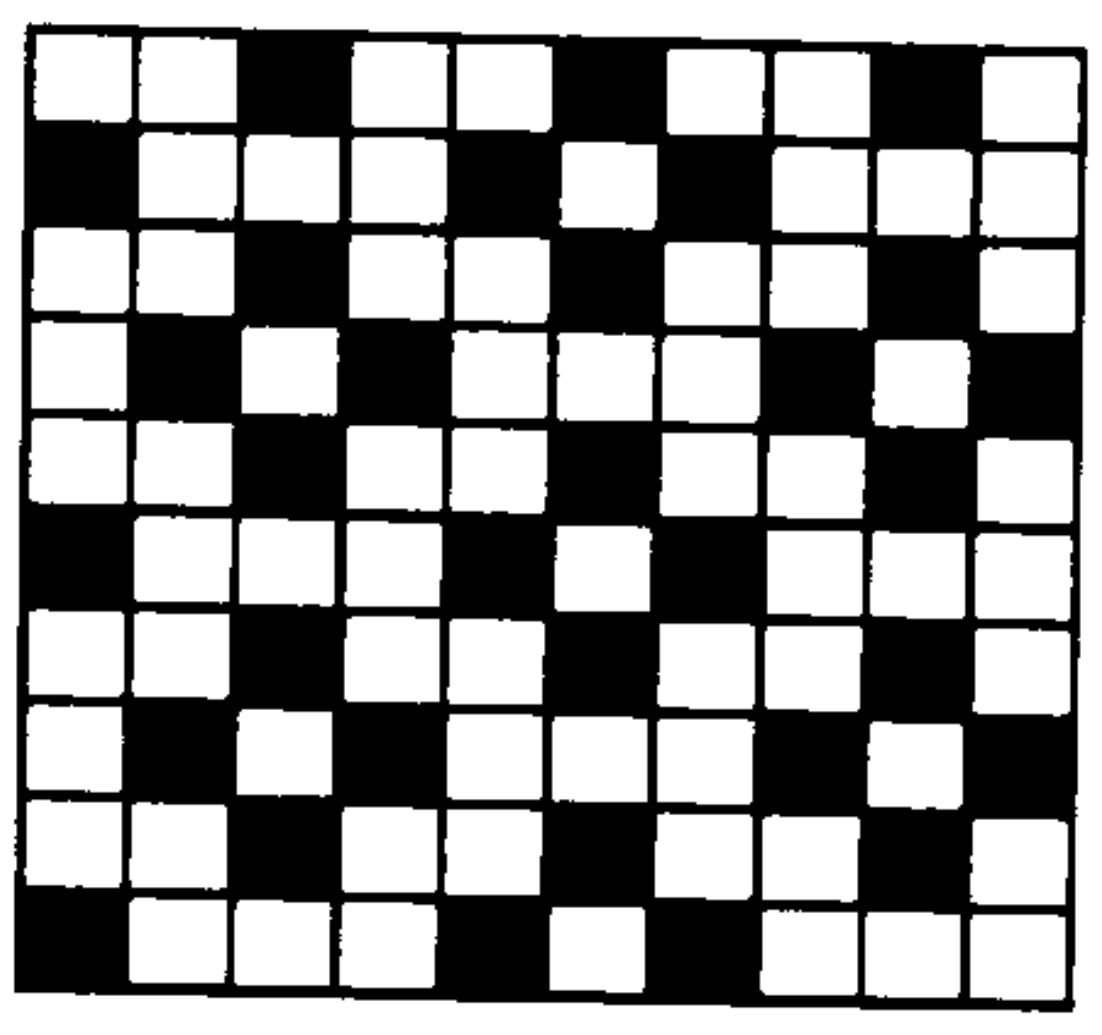
Please post completed questionnaire in the box provided or return to: James Stiller, Department of Health & Social Sciences, Francis Close Hall, University of Gloucestershire, Cheltenham, GL50 4AZ. Or Email: jstiller@glos.ac.uk

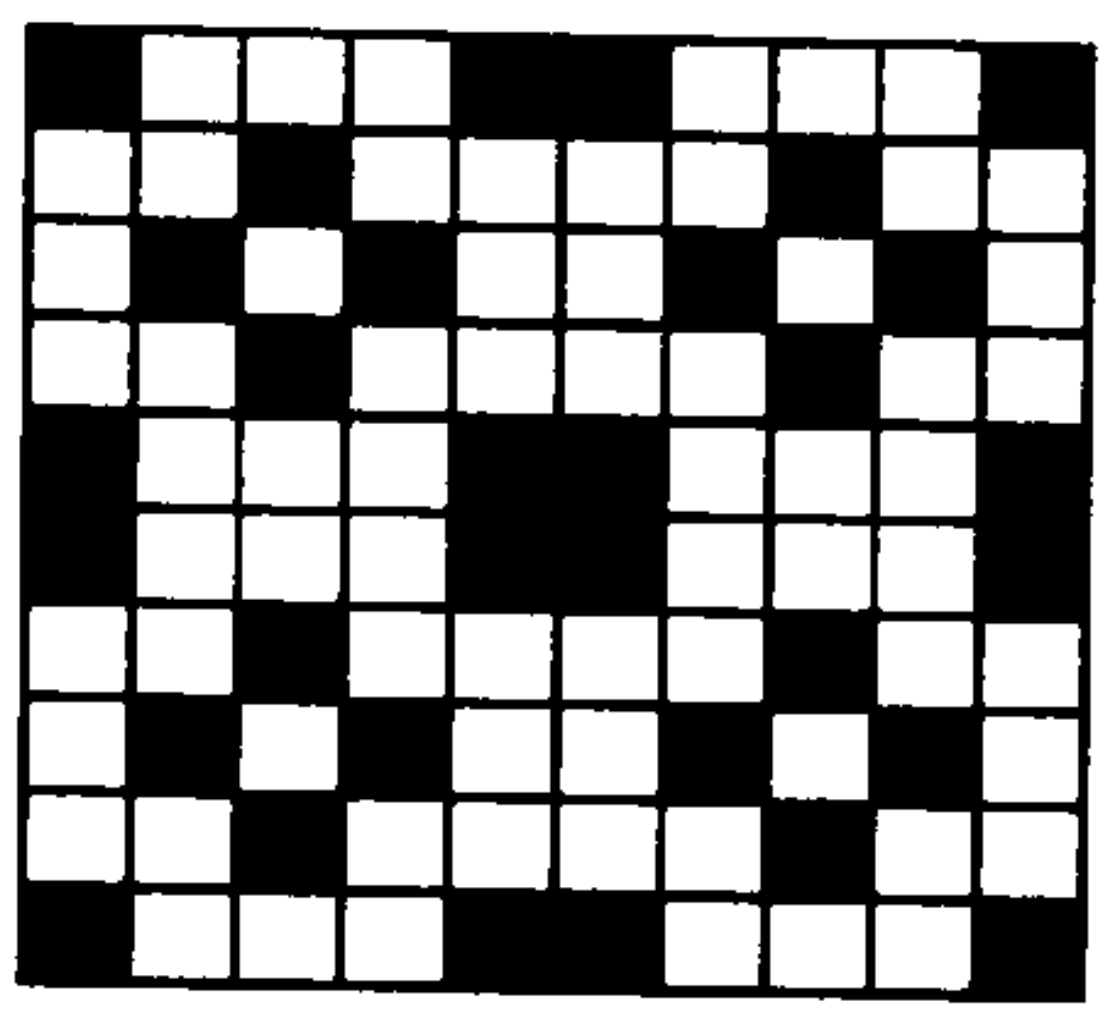
Pattern pilot study: Questionnaire 2

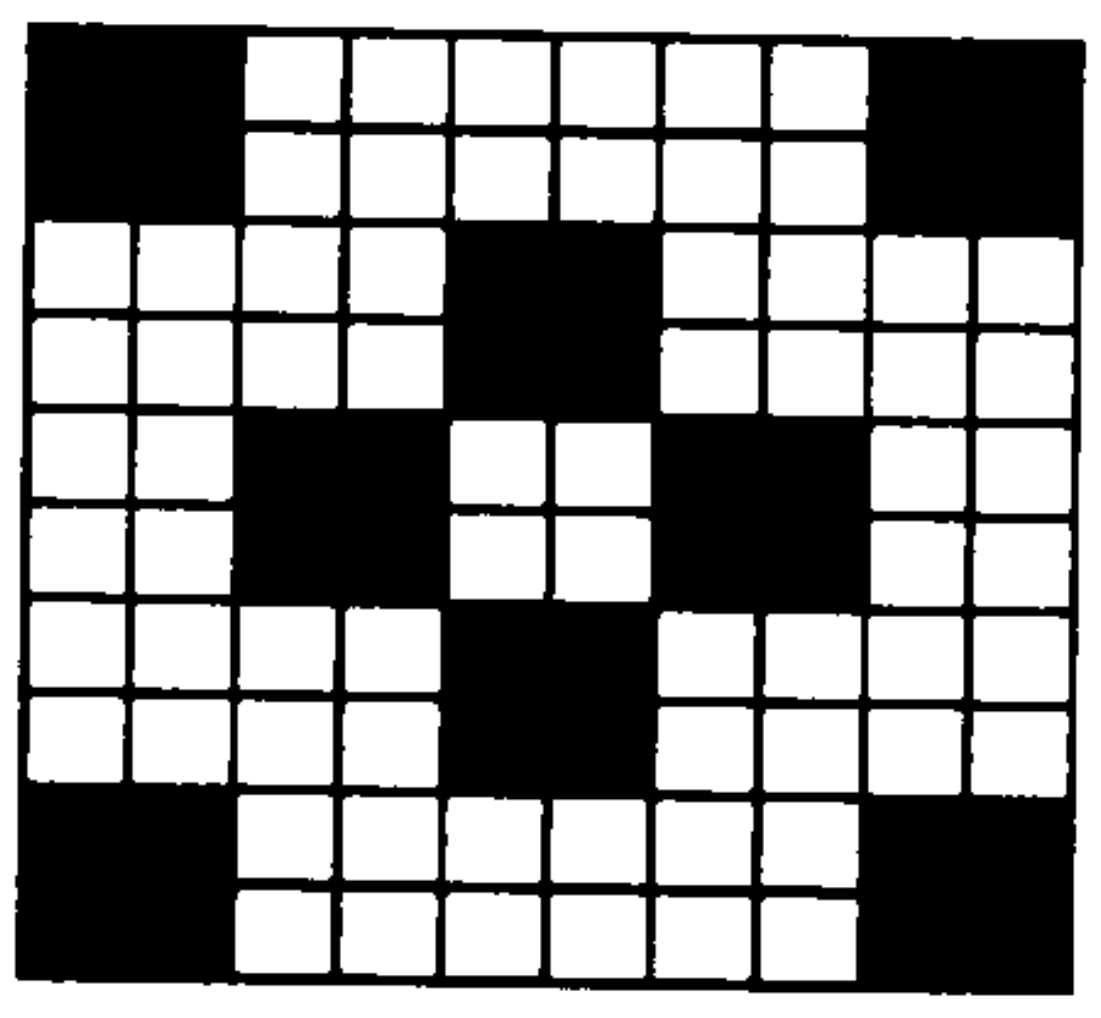
WHAT IS A PATTERN?

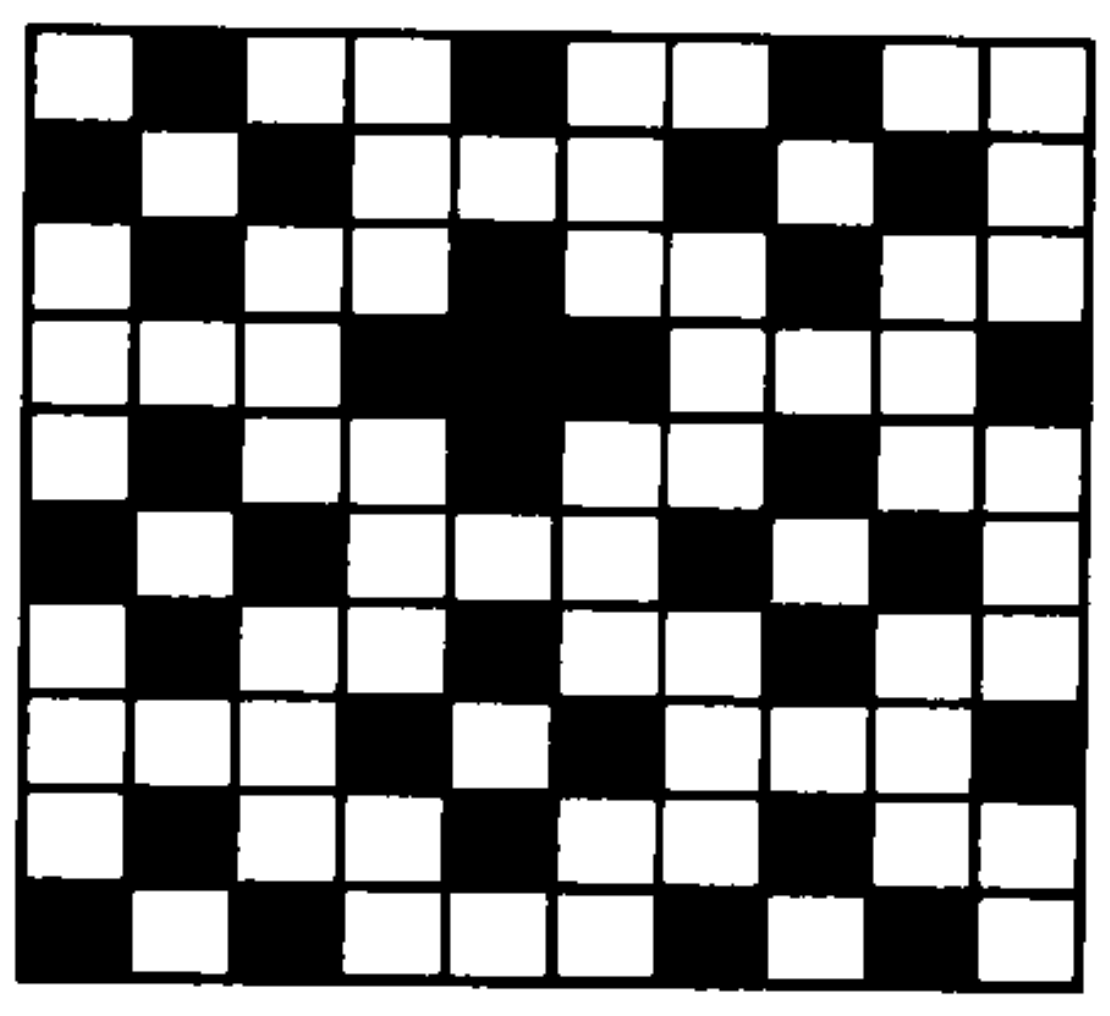
1) Please rate the pictures below according to how much each picture resembles your view of what a pattern is. (*Where 5 = most pattern like; and 1 = least pattern like)*

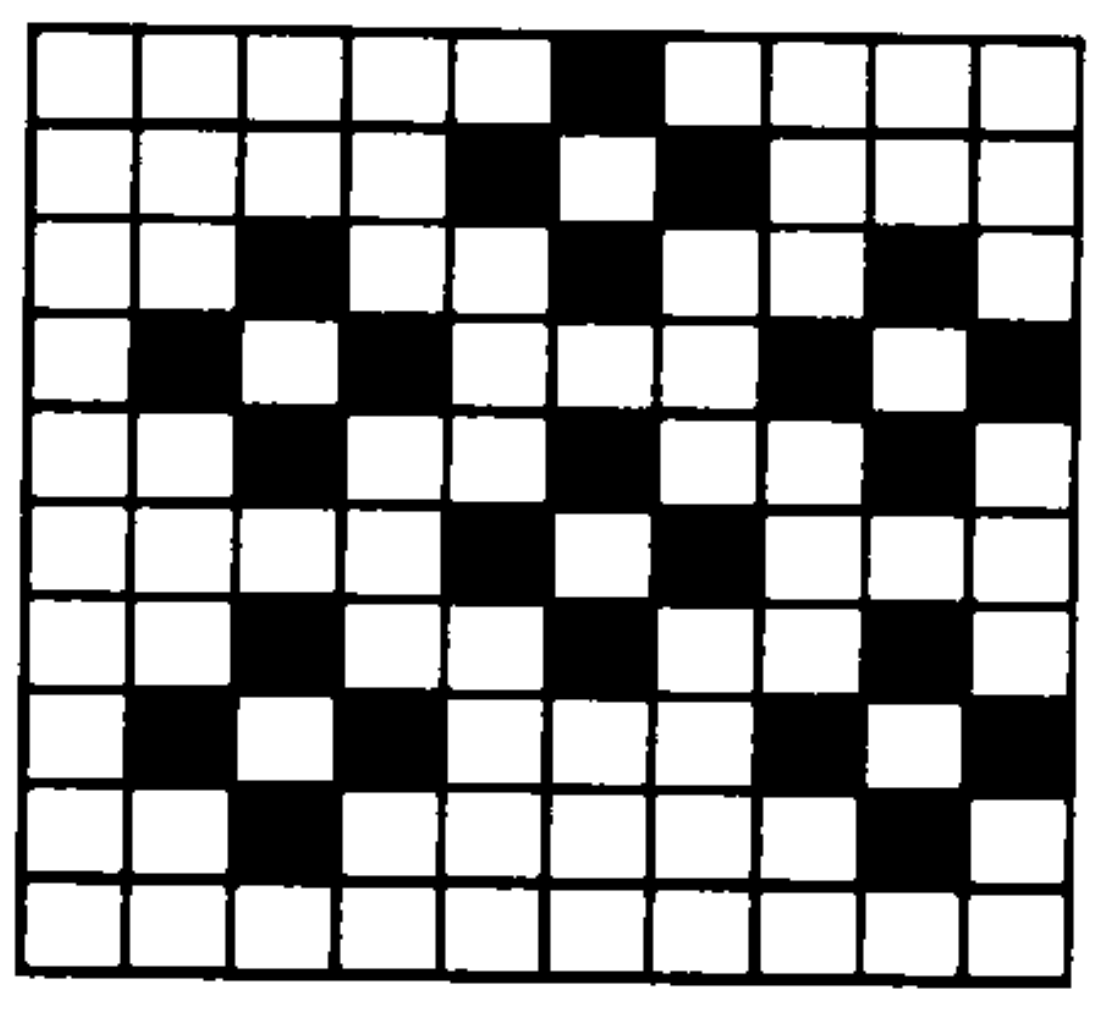

I

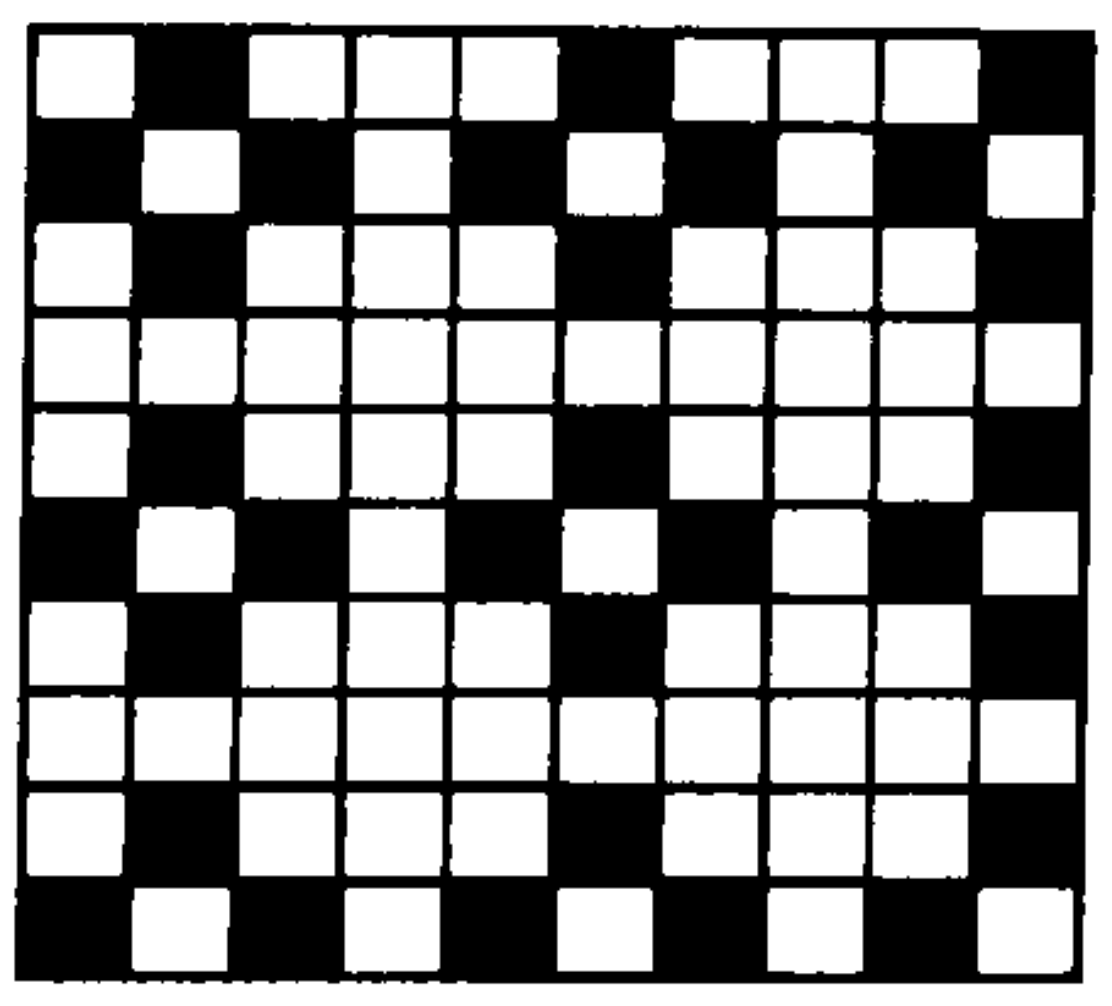

J

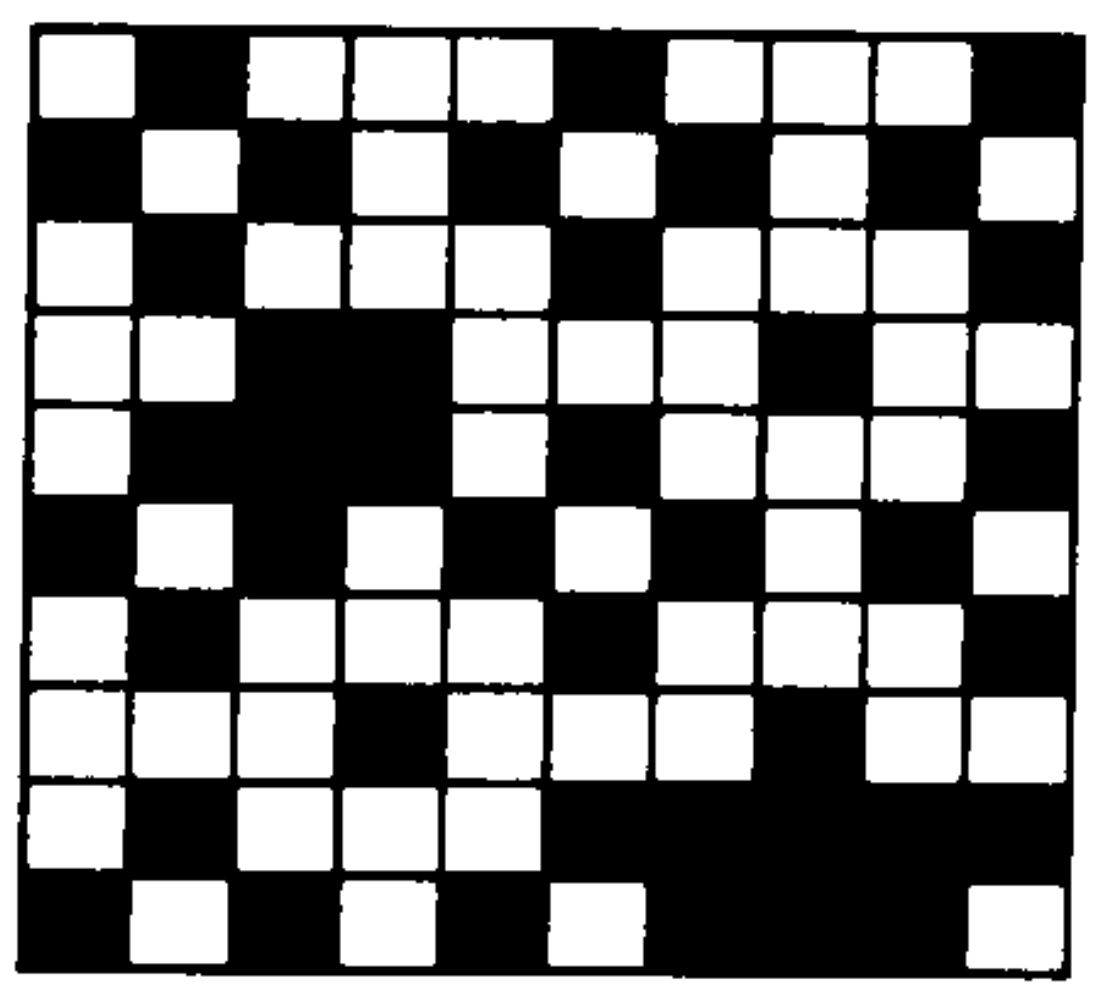

K


L


M


N


O


P

2) Which of the following terms is most important when describing what a pattern is? *Please put a tick by the most appropriate answer(s)*

- Symmetry (e.g. rotation, repetition or reflection) ☐
- Repetition ☐
- Reflection ☐
- Novelty ☐
- Pleasing to the eye ☐
- Complexity ☐
- Other (please specify)..

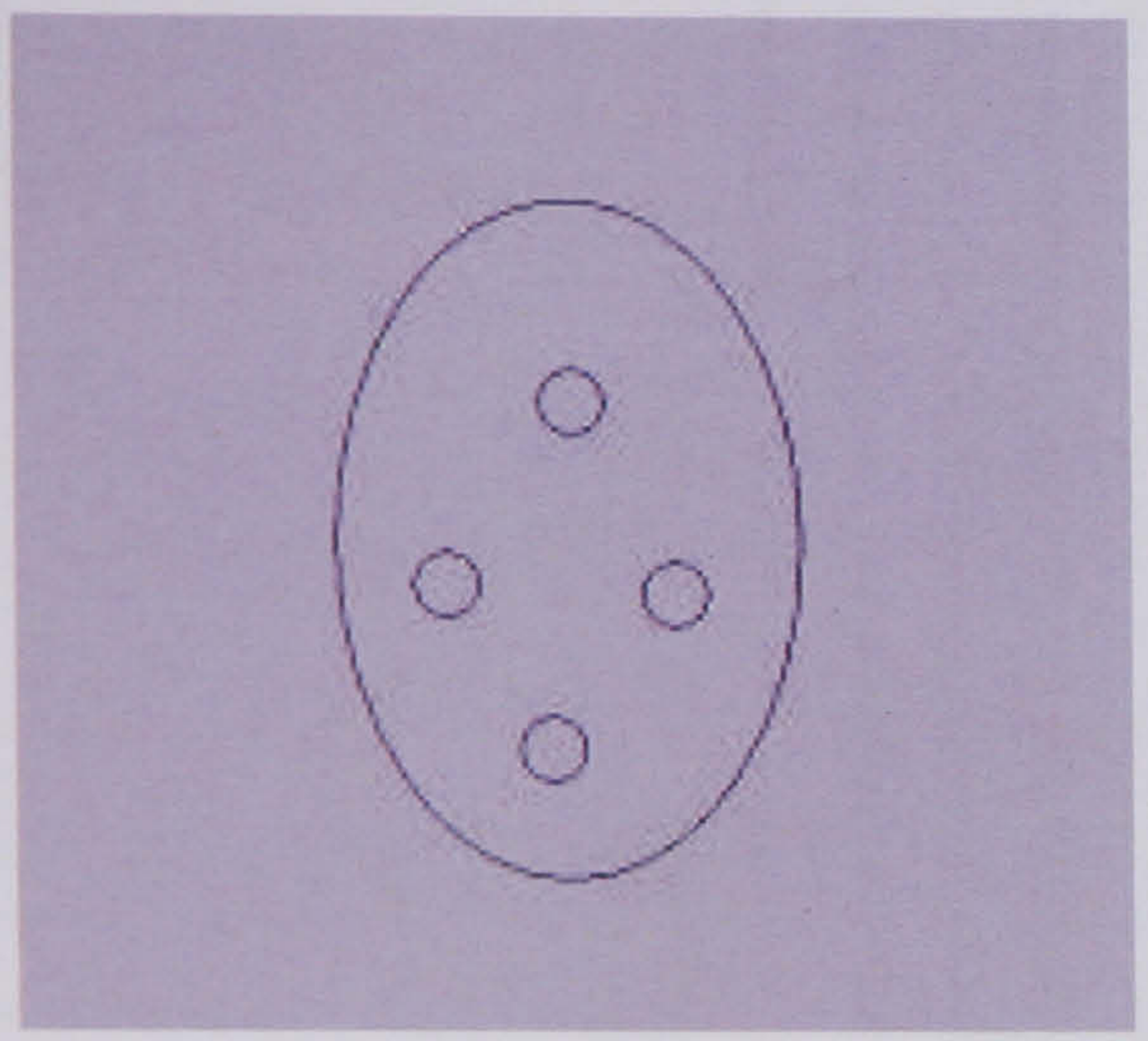
Please post completed questionnaire in the box provided or return to: James Stiller, Department of Health & Social Sciences, Francis Close Hall, University of Gloucestershire, Cheltenham, GL50 4AZ. Or Email: jstiller@glos.ac.uk

Face pilot study:

FACES

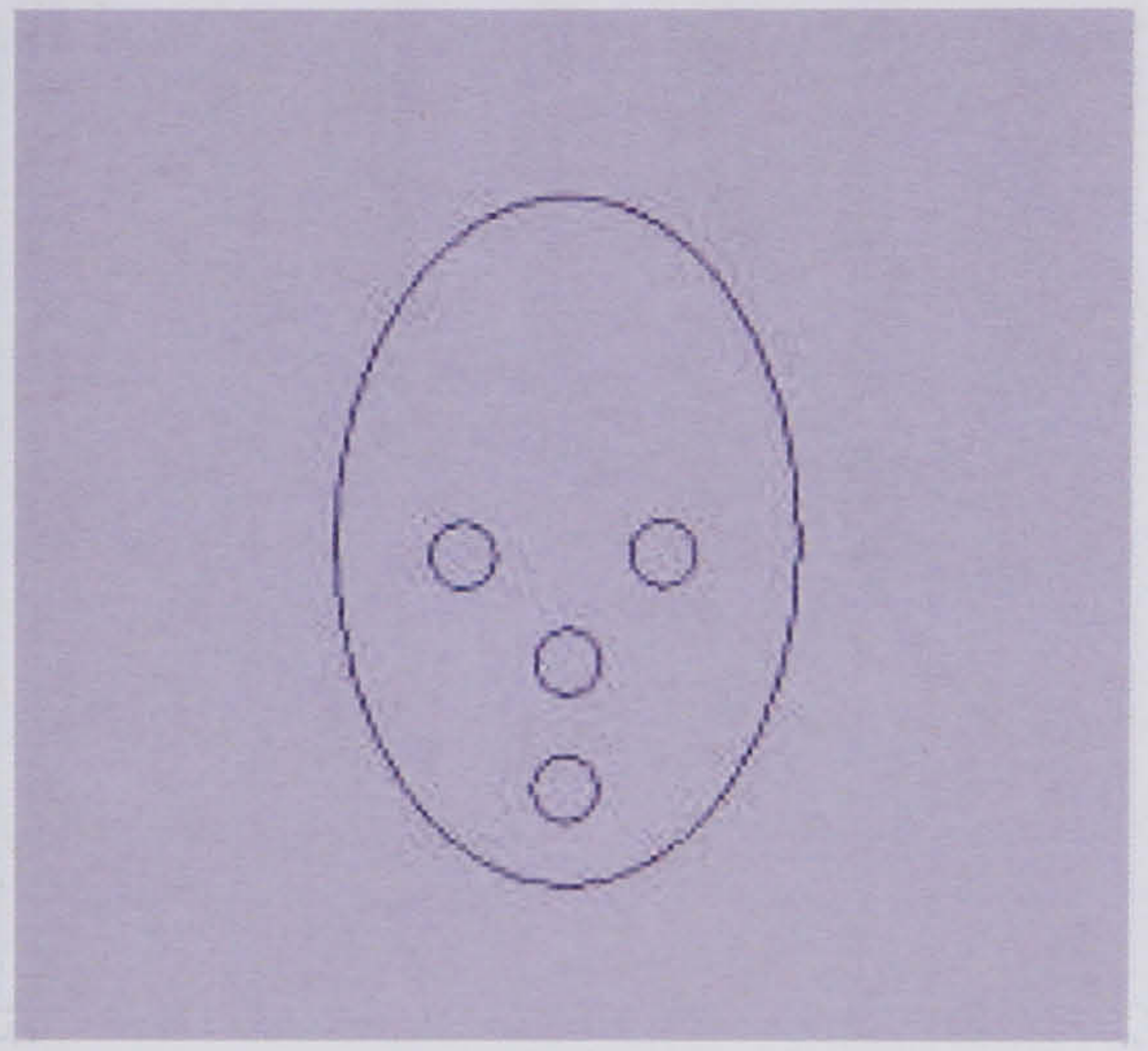
Look at each of the pictures carefully for a few seconds. Please rank these images in order of which one is the most face like.
1 = least face like and 4 = most face like.

Please place your answers in the box below each image



☐

☐



☐

☐

All data and results will be kept anonymous, thank you for taking part in this experiment. For more information regarding this experiment please contact James Stiller: jstiller@glos.ac.uk

Example of inter-trial questionnaire from the abstract masking experiment:

ID____________

Inter-trial questionnaire

Please rate the following questions on the scale provided (circle appropriate answer)

	Not very				Very
1) How confident are you in your responses?	1	2	3	4	5
2) How distracted are you by your surroundings?	1	2	3	4	5
3) What is your level of interest in the task?	1	2	3	4	5
4) How distracted are you by the masking pattern?	1	2	3	4	5
5) How comfortable do you feel with the procedure?	1	2	3	4	5
6) How much are you focusing on the patterns?	1	2	3	4	5
7) How often do you feel you are guessing?	1	2	3	4	5

Please list any criteria that you use to help in identifying the patterns

____
____
____
____
____
____

Please add any other comments you may have about the test (if any) below

____
____
____
____
____
____

Example of the washing line questionnaire (filled out by researcher):

Washing-line experiment

Age:
Gender:
Participant:

All questions to be answered in all conditions, participant is allowed to take as long as they feel they need before answering (this is not a reaction time expt!). Please indicate if the participant reports a bias in perception to either the figure on their left or right hand-side (but only if they raise the issue).

Condition A

	Answer Y (yes) or N (no)	1m	3m	5m	Bias?
a)	Were you aware of the intermediate faces?				
b)	Were you aware of the presence of the end figures?				
c)	Could you see the yes of the end figures?				
d)	Could you see the mouth of the end figures?				

	On a scale of 1 to 7; 1= not very & 7 =very				
e)	How clearly could you see the faces of the two end figures?				
f)	How clearly could you see the detail of the shirts on the two end figures?				
g)	How clearly can you see the face of the figure you are looking at? (i.e. fixation figure)				

Condition B

	Answer Y (yes) or N (no)	1m	3m	5m	Bias?
a)	Were you aware of the intermediate faces?				
b)	Were you aware of the presence of the end figures?				
c)	Could you see the yes of the end figures?				
d)	Could you see the mouth of the end figures?				

	On a scale of 1 to 7; 1= not very & 7 =very				
e)	How clearly could you see the faces of the two end figures?				
f)	How clearly could you see the detail of the shirts on the two end figures?				
g)	How clearly can you see the face of the figure you are looking at? (i.e. fixation figure)				

Condition C

	Answer Y (yes) or N (no)	1m	3m	5m	Bias?
a)	Were you aware of the intermediate faces?				
b)	Were you aware of the presence of the end figures?				
c)	Could you see the yes of the end figures?				
d)	Could you see the mouth of the end figures?				

	On a scale of 1 to 7; 1= not very & 7 =very				
e)	How clearly could you see the faces of the two end figures?				
f)	How clearly could you see the detail of the shirts on the two end figures?				
g)	How clearly can you see the face of the figure you are looking at? (i.e. fixation figure)				

Additional comments:

Appendix C

Tests for normality and homogeneity

Tests for normality and homogeneity

Below are additional tables and results not included in the main text regarding tests for normality and tests for homogeneity of variance.

i) Chapter 5:

a) Tests for normality and homogeneity for ***abstract pattern*** masking experiment

Table a: Kolmogorov-Smirnoff test for normality

ISI	Pattern	n	z	*p*
0	random	16	0.694	0.721
	repetition	16	0.722	0.674
	reflection	16	1.027	0.242
	repetition and reflection	16	0.654	0.786
14	random	16	0.73	0.661
	repetition	16	0.5	0.964
	reflection	16	0.75	0.627
	repetition and reflection	16	0.545	0.928
42	random	16	0.546	0.927
	repetition	16	0.803	0.539
	reflection	16	0.716	0.684
	repetition and reflection	16	0.797	0.549
96	random	16	0.781	0.575
	repetition	16	0.776	0.583
	reflection	16	0.769	0.596
	repetition and reflection	16	0.719	0.68
208	random	16	0.669	0.761
	repetition	16	0.513	0.955
	reflection	16	1.058	0.213
	repetition and reflection	16	0.817	0.516

Homogeneity of variance for abstract patterns: $F_{14,225} = 1.824$, p= 0.04

b) Test for normality for ***common direction*** experiment

Table b: Kolmogorov-Smirnoff test for normality

ISI	Pattern	n	z	p
0	Random direction	15	0.617	0.841
	Common direction	15	0.633	0.818
14	Random direction	15	0.575	0.896
	Common direction	15	0.845	0.473
28	Random direction	15	0.685	0.736
	Common direction	15	0.646	0.799
42	Random direction	15	0.821	0.511
	Common direction	15	0.764	0.604
56	Random direction	15	1.267	0.081
	Common direction	15	0.727	0.667

c) Tests for normality and homogeneity for pattern conditions used in the ***axis orientation***

Table c: Kolmogorov-Smirnoff test for normality

ISI	Pattern	n	z	p
0	diagonal	15	1.22	0.102
	horizontal	15	0.701	0.71
	vertical	15	0.803	0.539
14	diagonal	15	0.904	0.388
	horizontal	15	0.865	0.443
	vertical	15	1.001	0.269
42	diagonal	15	0.833	0.492
	horizontal	15	0.971	0.302
	vertical	15	0.687	0.732
96	diagonal	15	0.747	0.632
	horizontal	15	0.929	0.353
	vertical	15	0.604	0.859
208	diagonal	15	1.926	0.001
	horizontal	15	1.658	0.008
	vertical	15	1.699	0.006

Homogeneity of variance: $F_{2,1797} = 33.650$, $p < 0.001$).

ii) Chapter 6

Tests for normality and homogeneity for pattern conditions used in the ***face masking experiment***

Table d: Kolmogorov-Smirnoff test for normality

Pattern	n	z	p
No change	21	0.621	0.836
Eyes	21	0.783	0.572
Mouth	21	1.026	0.243

Homogeneity of variance: $F_{1,40} = 1.265$, $p = 0.27$

iii) Chapter 7

Test for homogeneity for pattern conditions used in the ***abstract hemifield*** masking experiment. Homogeneity of variance: $F_{4,195} = 2.737$, $p = 0.03$

iv) Chapter 8

a) Test for homogeneity for conditions used in the ***washing line*** experiment. Homogeneity of variance: $F_{2,501} = 1.224$, $p = 0.295$

b) Test for homogeneity and normality for pattern conditions used in the ***computer based group perception*** experiment.
Homogeneity of variance (faces x Tardis x Muddled faces):
$F_{2,147} = 0.122$, $p = 0.886$

Table e: Kolmogorov-Smirnoff test for normality

Pattern	**n**	**z**	***p***
Face	50	0.689	0.73
TARDIS	50	0.58	0.89
Muddled Face	50	0.818	0.515

Appendix D

Post-hoc t-tests with Bonferonni's correction

Post hoc tests

Below are the results tables for the post hoc paired t-tests with Bonferroni's correction for the 2-way within-participants repeated measures ANOVAs.

a) CHAPTER 5

i) Differences between symmetry types and ISI

Comparisons between pattern types: Random, Repetition, Repetition & Reflection, and Reflection

Pattern pairs	t	df	*p*
random - repetition	-1.13707	79	1.000
random - repetition & reflection	-0.87308	79	1.000
random - reflection	-1.05413	79	1.000
repetition - repetition & reflection	0.171718	79	1.000
repetition - reflection	0.05672	79	1.000
repetition & reflection - reflection	-0.12193	79	1.000

The p values were multiplied by 6 (no. of comparison pairs) for Bonferroni's correction

Comparisons between ISIs: 0, 14, 42, 96, and 208ms.

ISI pairs	t	df	*p*
0 - 14	-2.00	63	0.500
0 - 42	-3.97	63	0.000
0 - 96	-14.56	63	0.000
0 - 208	-17.26	63	0.000
14 - 42	-1.58	63	1.000
14 - 96	-10.66	63	0.000
14 - 208	-14.06	63	0.000
42 - 96	-8.83	63	0.000
42 - 208	-11.65	63	0.000
96 - 208	-4.01	63	0.000

The p values were multiplied by 10 (no. of comparison pairs) for Bonferroni's correction

ii) The effect of number of variants on patterns with reflective symmetry and ISI

Comparisons between the numbers of possible variants

Variant pairs	t	df	*p*
2 - 4	0.623	79	1.000
2 - 8	0.817	79	1.000
4 - 8	0.239	79	1.000

The p values were multiplied by 3 (no. of comparison pairs) for Bonferroni's correction

Comparisons between ISIs: 0, 14, 42, 96, and 208ms

ISI pairs	t	df	*p*
0 - 14	-2.18284	47	0.340
0 - 42	-4.04647	47	0.000
0 - 96	-14.455	47	0.000
0 - 208	-13.9521	47	0.000
14 - 42	-2.0168	47	0.490
14 - 96	-10.1196	47	0.000
14 - 208	-13.0103	47	0.000
42 - 96	-8.07041	47	0.000
42 - 208	-4.94416	15	0.000
96 - 208	-3.06868	47	0.040

The p values were multiplied by 10 (no. of comparison pairs) for Bonferroni's correction

iii) Orientation of axis of reflection and ISI

The effect of number of elements in patterns with repetition

Repeated elements

Repeated element pairs	t	df	*p*
1 - 2	-0.820	79	1.000
1 - 4	-1.172	79	1.000
2 - 4	-0.242	79	1.000

The p values were multiplied by 3 (no. of comparison pairs) for Bonferroni's correction

Comparisons between ISIs: 0, 14, 42, 96, and 208ms

ISI pairs	t	df	*p*
0 - 14	-0.608	47	0.546
0 - 42	-2.969	47	0.005
0 - 96	-15.296	47	0.000
0 - 208	-16.744	47	0.000
14 - 42	-2.049	47	0.046
14 - 96	-10.650	47	0.000
14 - 208	-12.907	47	0.000
42 - 96	-8.745	47	0.000
42 - 208	-10.788	47	0.000
96 - 208	-4.308	47	0.000

The p values were multiplied by 10 (no. of comparison pairs) for Bonferroni's correction

b) CHAPTER 6

i) Distorted face x normal face x ISI

Differences between eyes and mouth for distorted face

ISI	t	df	*p*
0	3.162	20	0.005**
14	2.769	20	0.012*
28	2.86	20	0.010*
56	1.862	20	0.077
154	3.101	20	0.006*

Comparisons between ISIs: 0, 14, 28, 56, and 154ms

ISI pairs	t	df	*p*
0 - 14	-1.06	41	0.294
0 - 42	-2.26	41	0.029
0 - 96	-3.53	41	0.001
0 - 208	-3.64	41	0.001
14 - 42	-1.35	41	0.186
14 - 96	-2.06	41	0.046
14 - 208	-3.20	41	0.003
42 - 96	-1.07	41	0.291
42 - 208	-1.86	41	0.070
96 - 208	-0.57	41	0.570

The p values were multiplied by 10 (no. of comparison pairs) for Bonferroni's correction

Appendix E

Results from the inter-trial questionnaires

Results of the interval questionnaires

Throughout the first masking experiment (Chapter 5), which took between 45 minutes and 1 hour, participants were asked to fill out a brief questionnaire to evaluate how comfortable they were with the test procedure during three break intervals. Figure *a* shows the results for how confident participants were in their answers, how distracted they were by the experimental environment, their level of interest in the task, their comfort with the procedure and instructions, and how often they felt they were guessing.

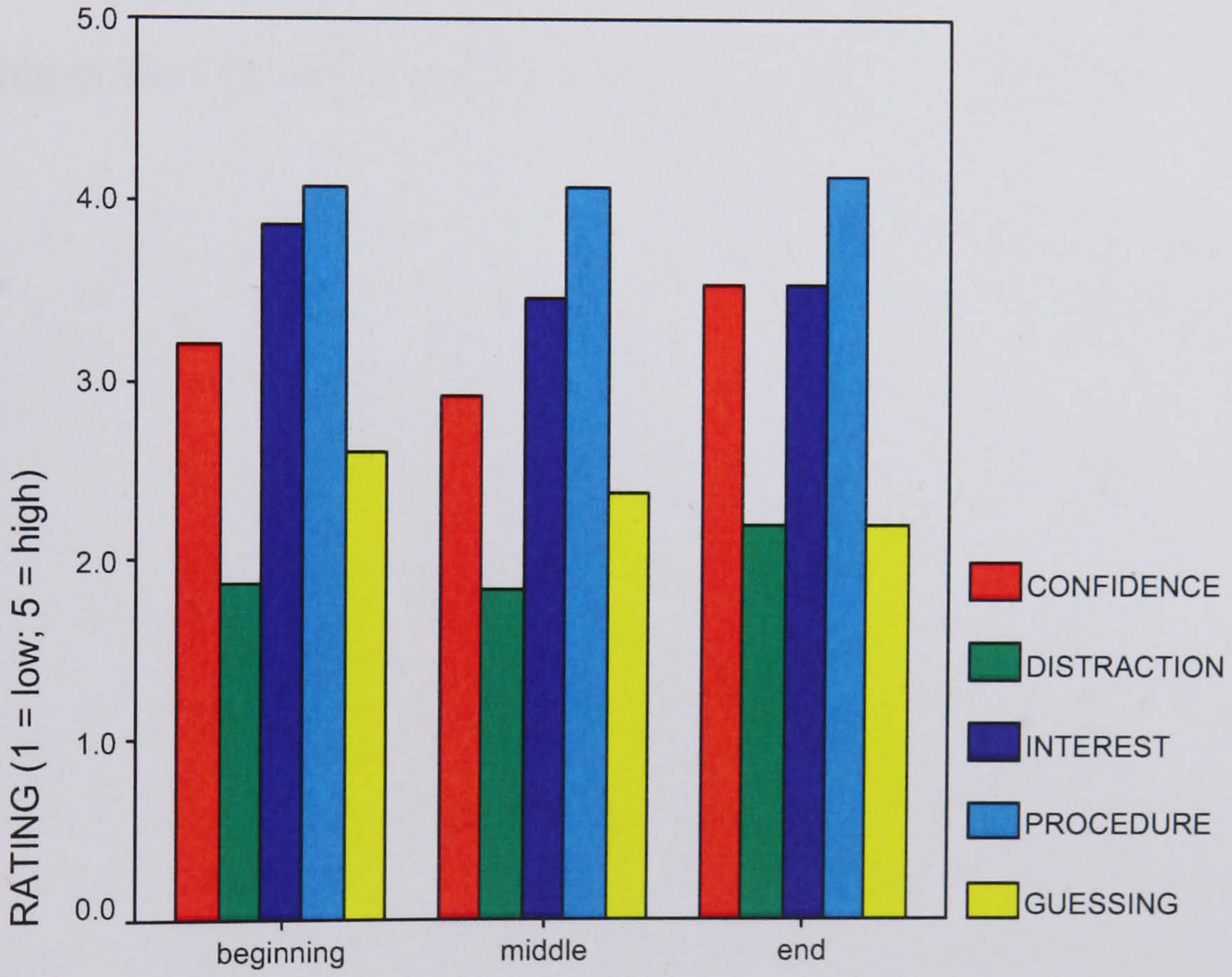


Figure *a*: Participant responses to the questionnaire.

The results indicate that the participants were comfortable with the test procedure and maintained interest in the task. As would be expected in a forced choice task the participants felt they were guessing approximately half the time. Participants also frequently stated that they tended to only see the top or top left corner of the target image during the masking procedure (Table *a*). This was therefore one of the reasons to investigate hemifield biases.

Table *a*: Participant comments regarding the criteria that they may have used to help in identifying the patterns.

Participant	Comment
1	Look for clusters of black areas.
2	For every guess I focus on a different corner of the grid
4	I try to focus on part of the pattern and not the whole grid - then changed strategy
5	Focused on specific corner
6	Focus on the top left of the box
9	Focused mainly on the top left of the image
10	I just look at the left corner
12	Try to focus on one part of the pattern
14	Concentrating on a small part of the pattern and focusing on the black square

An example of the Inter-trial questionnaire is presented in Appendix.

Appendix F

The "with noise" abstract pattern masking experiment

"With noise" Checkerboard masking experiment

Introduction

The "with noise" experiment was conducted to investigate the effect of adding noise to the saliency of different pattern types. The backing grid was added to the checkerboard stimuli with the intention of encouraging participants to have to analyse the patterns in a more serial manner.

The participants had to identify whether or not an image presented post masking was the same or different to the target image. The results were then converted using SDT to measures of accuracy (d') and response bias (c').

Methods

Participants

Condition without background noise

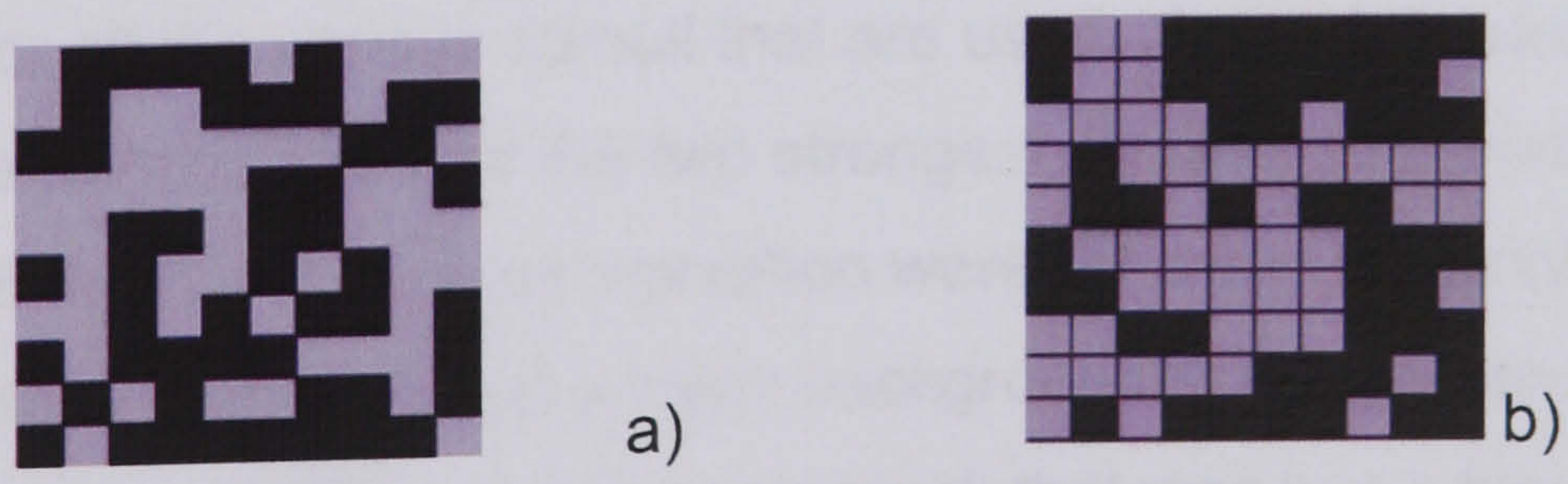
Sixteen participants, 6 male and 10 female were obtained from an opportunistic sample at the University of Gloucestershire. All participants were offered £5 compensation for their time regardless of the number of trials they completed. All participants were aged between 19 and 40 years old all and had Normal or corrected-to-normal vision. All the participants completed all the trials in the experiment. All participants provided their written informed consent prior to taking part in the experiment and were free to leave the experiment at any time. 13 participants completed all the trials (538 trials), 2 participants withdrew after three blocks of trials (319 trials) and one participant withdrew after the practice trial session (16 trials).

Apparatus

The computer set up as described in the general methodology, chapter 4, was used.

Stimuli

The stimuli used were 10 x 10 checkerboard patterns (see appendix?). The patterns consisted of black squares on a grey checkerboard background (see figure 3 for examples). The stimuli were split up into 4 distinct groups, random, reflective symmetry, repetition, and patterns containing repetition and reflective symmetry (see figure 3). The main symmetry stimuli were based upon randomly generated patterns so that there would be no aesthetic bias on the part of the experimenter in the production of the stimuli. To generate the random patterns a random number generator, where each number corresponded to a square present on the 10x10 grid, was used. The random patterns were then used to create the various symmetry types either by reflecting the bottom left corner or left half of the image. In order to counterbalance for subsequent variations in the proportion of black checks, and therefore differences in luminance, each stimulus was also presented as a negative of itself. Each stimulus was presented in a variety of orientations to control for the axis of symmetry. A two-alternative-forced-choice procedure was used so that there was a 50/50 chance of guessing a correct answer. The symmetry patterns were all derived from the randomly generated patterns, see figure 3 for examples of the various patterns types (see appendix for all basic patterns used in the experiment). These basic patterns were presented in all rotations and in negative to counterbalance any luminance biases and orientation bias. In the "with noise" condition the checkerboard patterns were presented with a bold black backing grid, see figure 4.



a) b)

Figure 4: Examples of two random patterns a) without background grid and b) with background grid.

For each condition 16 different stimuli were generated, 8 of these were based on a 10x10 random grid and 8 on a 5x5 random grid. This was to manipulate the clustering of black checks in the symmetry types and provide a comparable measure to the check size condition in the Mancini et al. (2005) experiments. All of the stimuli were presented in the centre of the monitor display at a size of 21cm x 21cm, the target area had an eccentricity of 9° from the fixation point. The luminances of the stimuli were 0.51 Lux for the black checks, 0.71 Lux for the grey background, and 0.81 Lux for the white areas of the masking stimulus.

5.2.4 Choice of inter-stimulus interval

Experiment	**ISI 1**	**ISI 2**	**ISI 3**	**ISI 4**	**ISI 5**
With backing grid	0	14	28	42	56

Table 2: The 5 inter-stimulus intervals for both experimental conditions

All of the ISIs were multiples of the screen refresh rate (approximately 14ms) to increase accuracy of timing. The ISIs were selected to reflect the stages of processing within the early visual system (see table). The key points being between 40ms and 60ms for the activation of area V1. In the "with-noise" experiment all ISIs were less than 60ms to target interruption of the signal while processing is predominantly feedforward.

5.2.5 Choice of Mask

The main problem with the mask was to find one that would be universally acceptable for all the various stimuli that are used. Several masks were tried on non-naïve participants and the two strongest masks compared. The two masks tested for the 'with noise' condition were the mask containing the diagonal straight white lines on a black background from the without background noise condition and second mask that was just a black square that covered the target stimulus. The swirl mask from experiment 1 had a reduced effect on the 'with noise' condition so was not tested further.

4 participants were recruited, 3 of these participants participated in the previous choice of mask experiment. The experiment consisted of 68 trials

and the choice of ISIs were the same as the ones outlined in the main methods for the 'with backing grid' condition.

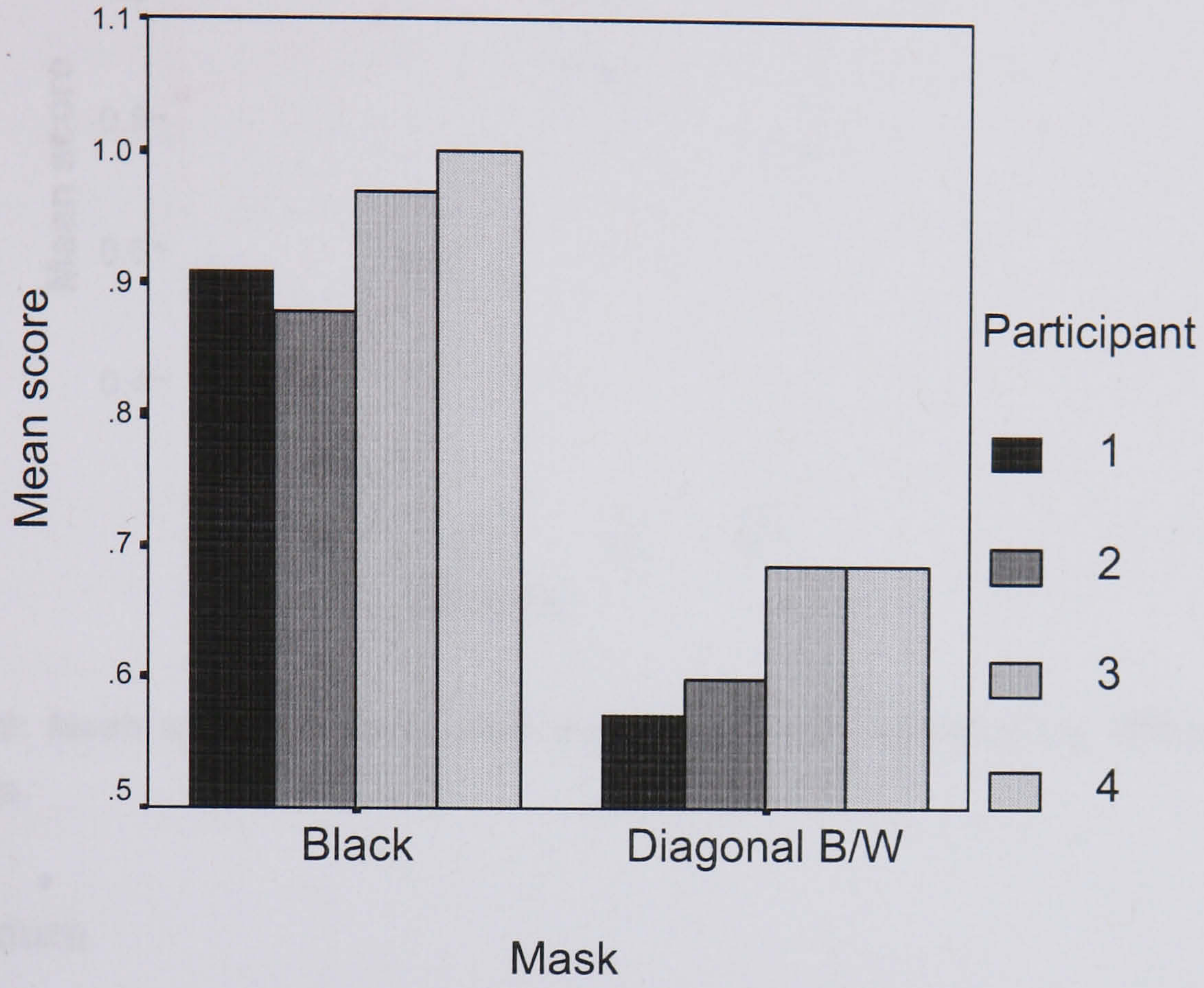


Figure 8: distribution of correct responses. Mean scores for participants 1 to 4 of 0.94, 0.88, 0.97, 1 respectively for the black mask. Mean scores for participants 1 to 4 of 0.57, 0.60, 0.69, 0.69 respectively for the diagonal black/ white mask.

The overall scores for each participant suggest that the diagonal mask is the most effective (figure 8). The mean scores for each mask were compared using a one-way repeated measures randomisation test to account for any autocorrelative effects as a result of the small sample size. It was shown that there was a significant difference in the distribution of scores ($p < 0.001$). The diagonal black/ white mask therefore appeared to be significantly more effective at blocking the target stimulus than the all black stimulus (figure 9).

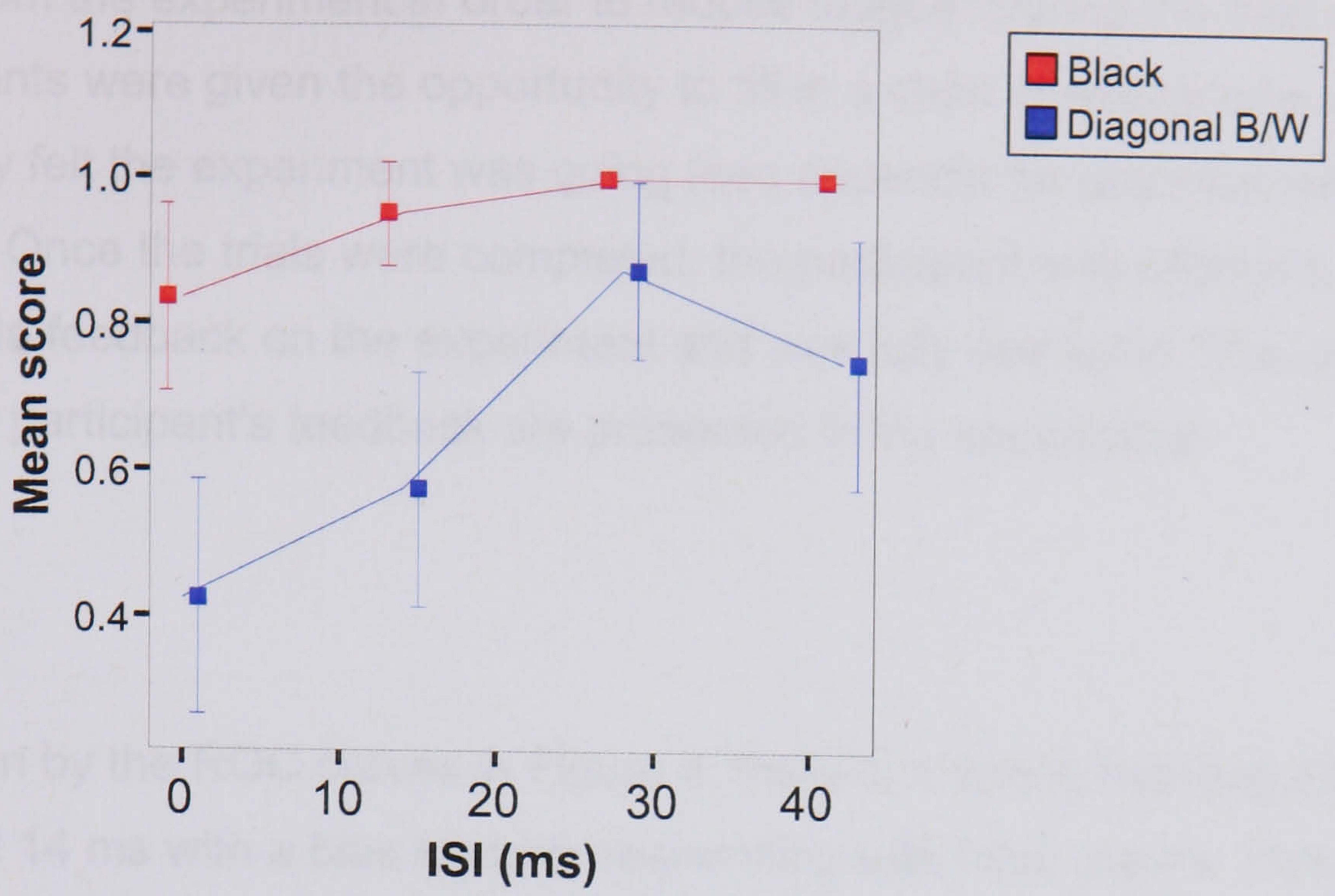


Figure 9: Mean score for each mask type. Error bars represent the 95% confidence intervals.

Procedure

The participants were seated in the experimental area. The researcher remained with the participant while they worked through the instructions but left as soon as the practice trials started so as not to distract the participant. In the practice trials the stimuli consisted of random patterns presented with an ISI of 500 ms. Once the participant had reached 80% accuracy on the practise trials they were able to continue to the main trials, the practise run consisted of 20 trials per cycle, all participants obtained 80% after one cycle of practise trials.

The masking procedure described in the general methodology chapter was used. The experiment took approximately one hour and consisted of 440 main trials. Each condition was presented to the participant 4 times at each ISI. The order of presentation was randomised to minimise priming or cueing effects.

The participant was told to identify whether the image presented at the end of each trial was the same as the one presented at the beginning of each trial.

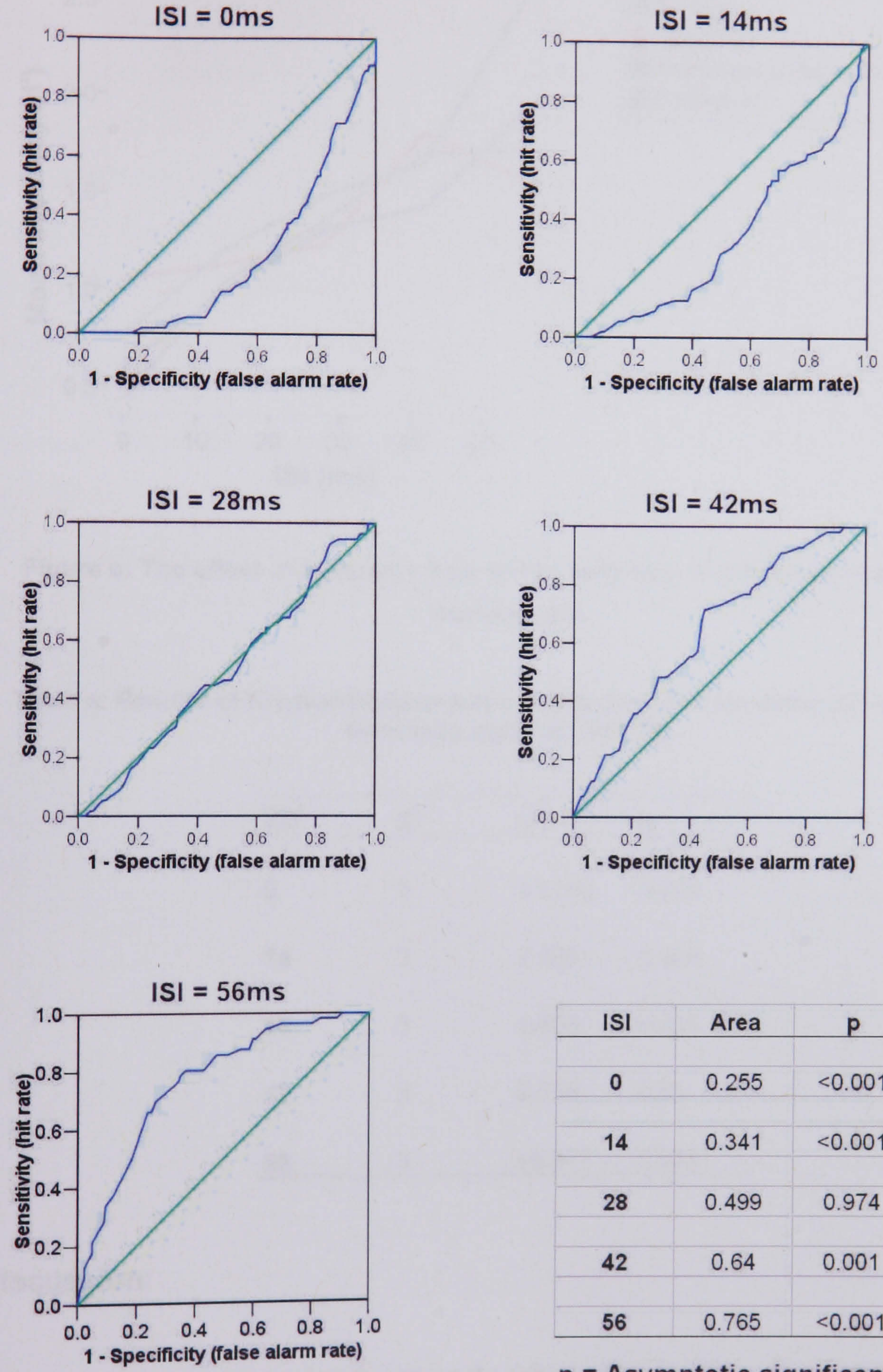
Every ten minutes the participant was given the opportunity to take a short break from the experiment in order to reduce fatigue. During the intervals the participants were given the opportunity to fill in a short questionnaire about how they felt the experiment was going (see appendix for questionnaire and results). Once the trials were completed, the participant was offered a chance to provide feedback on the experiment and was fully debriefed. The results from the participant's feedback are presented in the appendices.

Results

As shown by the ROC curves in Figure *a*, there is a strong masking effect at 0ms and 14 ms with a bias towards responding with false alarms. However at 28ms there is neither a bias towards false alarm or correct identification, this suggests that this could be a point where the target stimulus begins to be more apparent and represents a shift from falsely believing a change has occurred to recognising the presence of the target stimuli.

With the backing grid there appears to be a lower threshold after which there is a significant bias towards correct responses. In the masking experiment without a backing grid this point was reached between 42ms and 96ms compared with the 28ms for the experiment with a backing grid. However, the ROC curves for the experiment with the backing grid exhibit more noise, i.e. the curve is not as smooth, when compared to the experiment without the backing grid.

The results suggest that the backing grid has little effect on early symmetry detection, as the graph shape in Figure *b* is still similar to that in Figures 5.11 and 5.12 (Chapter 5). The results of a Kruskal-Wallace test show that there are significant differences between the detection of symmetry types at 0ms and 56ms (Table *a*). At 0ms there is still and advantage for repetition and at 56ms there appears to be an advantage for reflection. However, it appears that the grid might be having an effect on repetition and random patterns at 56ms, as there appears to be a levelling off in the shape of the lines (Figure *b*). This could suggest that the reflective patterns are still popping-out from the background while the serial processing of repetition and random patterns at higher ISIs is disrupted by the presence of the backing grid.



ISI	Area	p
0	0.255	<0.001
14	0.341	<0.001
28	0.499	0.974
42	0.64	0.001
56	0.765	<0.001

p = Asymptotic significance

Figure a: Graphs show ROC curves for each ISI, table shows area under curves and asymptotic significance.

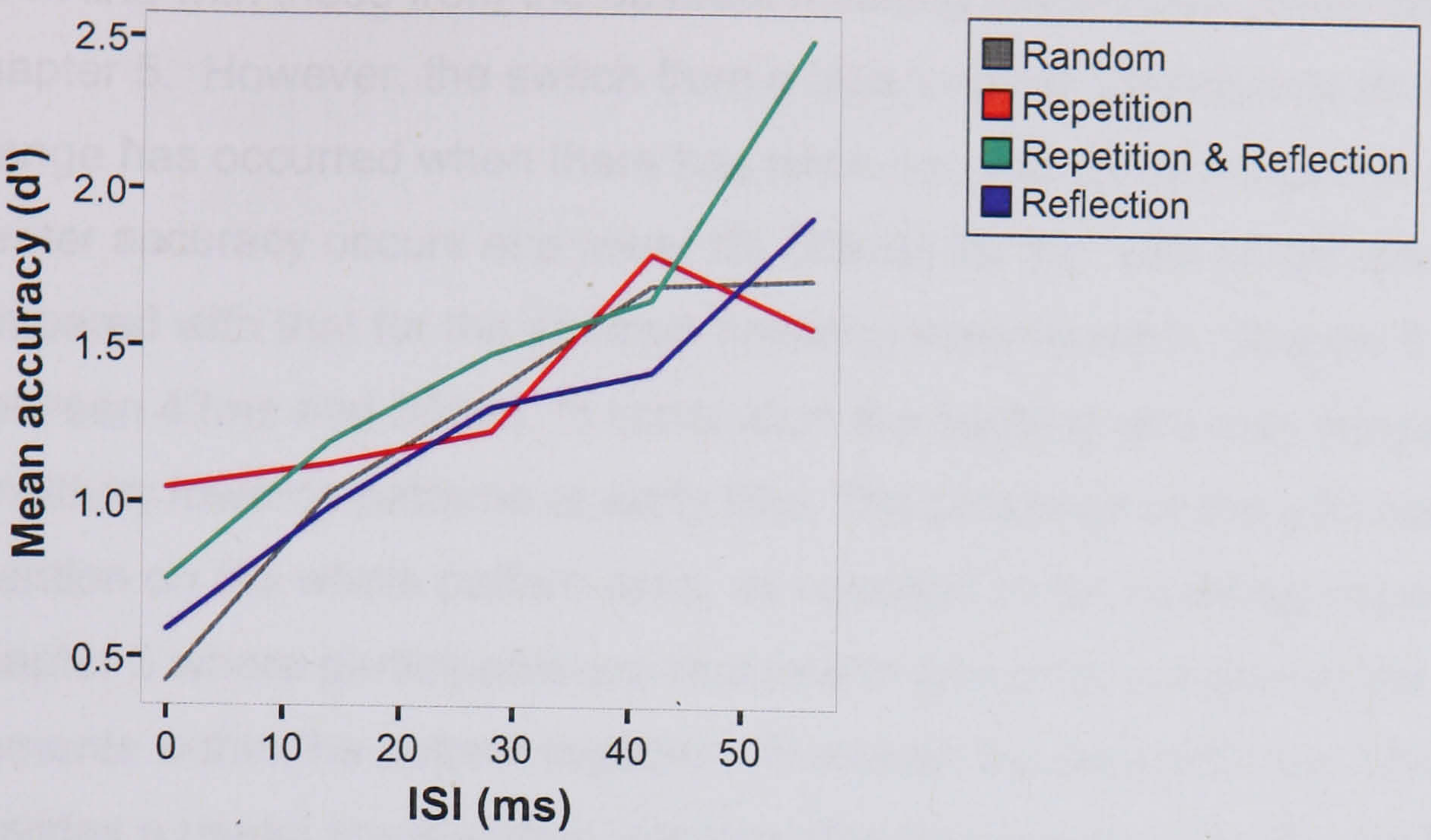


Figure b: The effect of symmetry type on the accuracy of pattern perception with backing grid.

Table a: Results of Kruskal-Wallace test for differences in accuracy (d') in between symmetry types at each ISI.

ISI	**Df**	χ^2	*p*
0	3	11.012	0.012
14	3	2.396	0.494
28	3	4.609	0.203
42	3	2.259	0.52
56	3	16.871	0.001

Discussion:

There appears to be a significant early advantage for the processing of repeated stimuli at early ISIs (0ms). The background grid does not appear to inhibit the processing of the target stimuli, however it may increase the reliance on serial processing, however patterns that contain both repetition and reflection appear to have a significant advantage at an ISI of 56ms. This may suggest that patterns that contain more than one symmetry type will have a perceptual advantage. In general, the results of the "with noise condition" are in line with those from the abstract masking experiment presented in Chapter 5. However, the switch from a bias towards participants thinking a change has occurred when there has been none to correct rejection and greater accuracy occurs at a lower ISI (28ms) for the "with noise" condition compared with that for the abstract masking experiment in Chapter 5 (between 42ms and 96ms). In conclusion the backing grid may increase sensitivity towards patterns at early ISIs. The presence of the grid may focus attention on the whole pattern area, as opposed to the masking experiment in Chapter 5 where participants are required to group (or not group) the elements within the pattern together. Therefore the experiment in Chapter 5 provides a useful investigation into how the participants actively construct patterns mentally, while the "with noise" experiment provides an insight into how each pattern may be processed serially at very early processing intervals.

Appendix G

Participant feedback from Washing line experiment (Chapter 8)

Participant feedback from the Washing line experiment

The majority of participants did not provide any feedback, however 7 of the participants did provide constructive feedback.

Participant	Participant feedback
48	Felt constrained by the intermediate faces, and was not sure about which face he was seeing
47	Felt that the intermediate faces merged with the end figures
39	Felt drawn to the left eye
53	Reported the intermediate faces being particularly distracting
28	Felt drawn to the left eye
18	Felt part way through the experiment that she could see everything and that distance from the stimuli had little effect.
16	Felt drawn to the end figure (left) and had trouble trying not to glance at it

Appendix H

Consent Forms

Example of standard consent form used in pilot studies:

UNIVERSITY OF
GLOUCESTERSHIRE

I understand that my participation in this project will involve *provide description e.g., completing questionnaires/computerized task and the amount of time that it will take*

I understand that my participation in this study is entirely voluntary and that I can withdraw from the study at any time for any reason without loss of payment *alternatively tell them there is no loss of course credit or anything else that is provided as an inducement to complete the research*

I understand that I am free to ask questions at any time. If for any reason I experience discomfort in any way I am free to withdraw or discuss my concerns with *include your name here and also an e-mail address.*

I understand that the information provided by me will be held anonymously such that it is impossible to trace the information back to me individually. I understand that, in accordance with the Data Protection Act, this information may be retained indefinitely. Finally, I also understand that at the end of the study I will be provided with additional information and feedback.

I, *space included for participant to print their name* consent to participate in the study conducted by *name of student, School of Health and Social Sciences, University of Gloucestershire.*

Signed:

Date:

Example of consent form used in masking experiments:

PATTERN PERCEPTION CONSENT FORM

Thank you for volunteering to take part in this study.

The study involves the rapid identification of visual patterns/ faces on a computer screen. The experiment will take approximately 1 hour including regular breaks between trials. *Participants are strongly advised to take these breaks.*

As the experiment involves looking at a computer screen for long periods of time it is advisable that if you regularly suffer from migraines or any photosensitive condition that you do not participate. It is also advisable that you make yourself as comfortable as possible before testing commences.

If at any time you wish to stop the experiment please let the researcher know immediately. You are free to withdraw from the study at any time during or after the testing.

All personal information will be treated strictly as confidential and will not be made publicly available or given to any other person.

Information generated by the experiment may be published, but no details will be divulged from which the participant can be identified.

A full debriefing will be provided after the experiment.

If you are happy with the above terms please sign and date the form below.

Signed_______________________________ Date___________

Example of consent form used in field of vision experiments:

WASHING LINE CONSENT FORM

Thank you for volunteering to take part in this study.

This study involves the rating of life-size images presented on a washing line.

If at any time you wish to stop the experiment please let the researcher know immediately. You are free to withdraw from the study at any time during or after the testing.

All personal information will be treated strictly as confidential and will not be made publicly available or given to any other person.

Information generated by the experiment may be published, but no details will be divulged from which the participant can be identified.

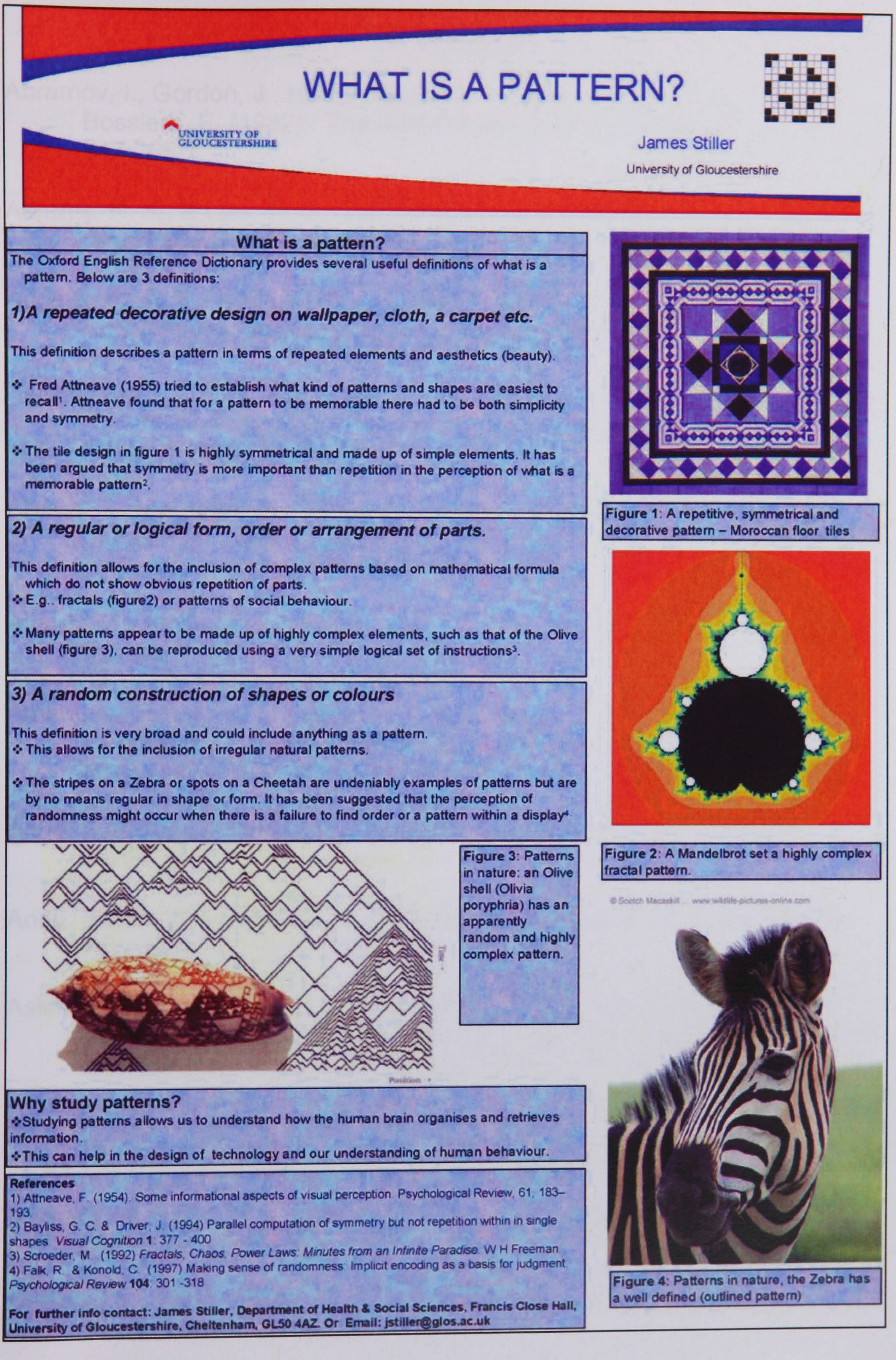
A full debriefing will be provided after the experiment.

If you are happy with the above terms please sign and date the form below.

Signed________________________________ Date____________

Appendix I

Pattern Poster/ handout displayed at the Cheltenham Science Festival 2003



WHAT IS A PATTERN?

UNIVERSITY OF GLOUCESTERSHIRE

James Stiller
University of Gloucestershire

What is a pattern?

The Oxford English Reference Dictionary provides several useful definitions of what is a pattern. Below are 3 definitions:

1)A repeated decorative design on wallpaper, cloth, a carpet etc.

This definition describes a pattern in terms of repeated elements and aesthetics (beauty).

- Fred Attneave (1955) tried to establish what kind of patterns and shapes are easiest to recall[1]. Attneave found that for a pattern to be memorable there had to be both simplicity and symmetry.
- The tile design in figure 1 is highly symmetrical and made up of simple elements. It has been argued that symmetry is more important than repetition in the perception of what is a memorable pattern[2].

Figure 1: A repetitive, symmetrical and decorative pattern – Moroccan floor tiles

2) A regular or logical form, order or arrangement of parts.

This definition allows for the inclusion of complex patterns based on mathematical formula which do not show obvious repetition of parts.

- E.g.. fractals (figure2) or patterns of social behaviour.
- Many patterns appear to be made up of highly complex elements, such as that of the Olive shell (figure 3), can be reproduced using a very simple logical set of instructions[3].

Figure 2: A Mandelbrot set a highly complex fractal pattern.

3) A random construction of shapes or colours

This definition is very broad and could include anything as a pattern.

- This allows for the inclusion of irregular natural patterns.
- The stripes on a Zebra or spots on a Cheetah are undeniably examples of patterns but are by no means regular in shape or form. It has been suggested that the perception of randomness might occur when there is a failure to find order or a pattern within a display[4]

Figure 3: Patterns in nature: an Olive shell (Olivia poryphria) has an apparently random and highly complex pattern.

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Figure 4: Patterns in nature, the Zebra has a well defined (outlined pattern)

Why study patterns?

- Studying patterns allows us to understand how the human brain organises and retrieves information.
- This can help in the design of technology and our understanding of human behaviour.

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