Sidoumou, Mohamed R, Bechkoum, Kamal ORCID logoORCID: https://orcid.org/0000-0001-5857-2763, Turner, Scott and Picton, Phil (2015) Multitasking in Emotion Modelling: Attention Control. In: 2015 International Conference on Affective Computing and Intelligent Interaction (ACII). IEEE Computer Society, pp. 308-314. ISBN 9781479999538

DOI: http://dx.doi.org/10.1109/ACII.2015.7344588
EPrint URI: https://eprints.glos.ac.uk/id/eprint/2892

2015 International Conference on Affective Computing and Intelligent Interaction (ACII)

Multitasking in Emotion Modelling
Attention Control

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Abstract
The work described in this paper is about building a general model capable of simulating human behaviour and emotions using virtual characters. To make the simulation realistic enough, virtual characters need to express emotions according to the environment and deal with those emotions in a parallel way where an emotional experience can be triggered at the same time as another emotional response. The virtual character will have perceptions, feel and express emotions and respond to different situations. To make the simulation realistic, we used a method allowing the virtual characters to execute tasks, perceive events and display emotions in a parallel way. To do that, we used the multiple resources model [1] to control the attention and to predict when two or more actions can be executed at the same time. The used emotional model is based on Scherer's theory [2]. However, in this paper we focus on the control of the attention as a part of the emotional process.

Keywords
Affective Computing; Emotion; Simulation; Multitasking; Workload;

I. Introduction

Emotions modelling has been approached by researchers with different objectives. Many of them modelled emotions for the purpose of simulation using characters endowed with cognition in a virtual environment, like FLAME [3] and WASABI [4]. Researchers use psychological theories of emotions as a basis to build a model ready to be implemented. They use their own interpretation of the psychological theories. Those interpretations might differ especially when addressing hidden assumptions. Among those theories, the appraisal family is the most used in simulation [5]. Those theories give a comprehensive guideline when modelling emotions. However, they rarely address the multitasking nature of the human body and mind. When an organism experiences an emotion it may trigger a coping action. During the execution of this action, its perceptions and cognition can still take part in other actions in parallel. As an example, a driver is listening to the radio while driving and hears a piece of news that may affect one of his goals. A coping strategy is to park and call a friend. While the driver is parking, he witnesses a crash. Executing the coping strategy does not prevent the driver from experiencing the emotion associated with the crash. Attention, cognition and actions can be executed in parallel [1]. Attention and cognition are included in the emotional process by theories such as Scherer's theory [6].

In this paper, the possibility and ability to attend to more than one event at the same time and executing more than one action at the same time is examined. An algorithm based on the multiple resources model [1] is implemented to direct the attention according to the goals and resources. A general model is presented. It uses many parameters that influence emotion. These parameters will not be addressed in this paper. Among them, personality traits are known to influence emotions [7].

II. Emotion

Before modelling emotions, we need to agree about what are we modelling and what do we mean by emotions. Will we model just the feelings? Or does the emotional process include many components? Theories differ on what is included in emotions and what is not included. Appraisal theories are componential and include many components.

Another question is, are every affective state classified as an emotion? From Scherer [8] point of view, the answer to this question is no. Affective states include emotions, mood, interpersonal stances, attitudes and personality traits [8]. What distinguish emotions from the other affective processes is that they are brief synchronized responses by an organism to the evaluation of an internal or external stimuli and their intensity are relatively higher than the other affective states [8]. In other words, appraisal is what triggers an emotion while other parameters may influence.

Scherer [8] also points out that a source of treating the terms emotions and feelings as synonyms is a source of confusion. In appraisal theories, subjective feeling may be identified as just one component among other emotional components.

III. Attention theories

In Scherer's model [2] attention is required at the earliest stage of the emotional process. Attention is used to check whether a stimulus is relevant or not and then requires further processing if it does. It allows us to attend to relevant events and by modelling it; it will be possible to create a more realistic artificial behaviour with an attention management policy. As an example, you are talking in the phone to your boss and he tells that you are promoted to a higher position. At the same time your kid dropped your cup of coffee. These two events will probably trigger two different emotions if they happened at two different moments but if they are happening at the same time, the affective outcome might be different. In appraisal theories this outcome will probably depend on the different stages and variables of the appraisal processes. Furthermore, the resources available for the emotional process will undoubtedly affect how a stimulus is appraised as those resources are limited and reasoning about two different concepts at the same time is not as easy as reasoning about only one per moment. When the available resources are not sufficient to deal with two tasks at the same time, a mechanism is used to allocate more resources to a competing stimulus over another, details are given about this in [9]. Another important aspect of attention in emotion is how attention is directed in an environment and how does that affect the affective state.

In most computational emotional models, components work sequentially, like a workflow; generally the process starts with attention, then an emotion is computed and finally an action is triggered. However, theories like Wicken's theory [10] state that human's mind can execute different tasks at the same time depending on the available resources. Thus, using such theories will allow us to simulate emotions related to events occurring at the same time according to the available resources. In this case the different modules should be able to work in parallel rather than in a sequential way.

Attention is directed either in top-down fashion or a bottom-up fashion [11]. A top-down approach is used when attention is directed by the goals and concerns or task demand. A bottom-up approach is used when an external stimulus takes the focus; salient stimuli, like hearing a loud sound.

Early attention theories depict attention as a single pool of resources like in [12] where it can be shared among different tasks. In those theories the resources are similar and each task requires a certain amount of resources from that pool. More recent theories suggest that humans have multiple types of resources and allocate those resources according to the attended tasks. In other words, a person can attend successfully to two tasks at the same time if those two tasks use different types of resources or if they require the same resource and the amount required by each task can be satisfied at the same time. One of those theories is Wicken's theory [1].

IV. Multiple resources models

An organism can attend to different tasks at the same time providing that they do not interfere with each other. To accurately simulate emotions, we propose to take into account how the body and mind handle many different tasks at the same time and how do we appraise situations in such cases. To attend to an event, we need to allocate certain resources to appraise that event as suggested by multiple resources theories. But what happens if the needed resources are not available? How do we carry simulation on in such cases? For this, we will use a theory dealing with multiple resources and performance. Wicken's theory [1] considers that there are four dichotomous dimensions accounting for variance in time- sharing performance. Each dimension is divided into two levels. If two tasks require the same level then they are more likely to interfere with each other than two tasks requiring two different levels. The fours dimensions are processing stages, perceptual modalities, visual channels, and processing codes. In processing stages according to Wicken, the resources used by perception and cognition appear to be the same. An interesting aspect in modelling human's behaviour is that Wicken states that the selection and execution of actions use different resources than perception and cognition. This suggests that perception/cognition and responses can be executed in parallel. Cognition and perception do share resources like working memory [1] and therefore two tasks, one involving cognition and the other involving perception will interfere with each other if executed at the same time. Next we will look at the different dimensions of Wicken's theory.

The perceptual modalities dimension is divided into visual and auditory. Wicken states that dividing attention between the eye and the ear can be done better than dividing the attention between tasks requiring the same modality at the same time. The reasons why time sharing cross modalities is better than time sharing intra-modalities are, two intra- modalities channels may need masking if they are too close to focus on just one of them and they need scanning if they are far from each other [1]. To model this, it is imperative to create a measurement method to compute how much two perceptual tasks are interfering with each other.

The visual channels dimension is divided into focal vision and ambient vision and those two modalities use separate resources [1]. This dimension is used only when perception is involved. We will not use this dimension in our model for the sake of simplicity.

The processing codes according to [1] is a dimension that defines the distinction between analogue/spatial processes and categorical/symbolic. Spatial tasks involve different resources than verbal task, whether during perception, cognition or responses. The figure 1 illustrates a three dimensional representation of the multiple resources model. In this figure, perception and cognition uses the same resources (verbal or spatial). Responding in the other hand uses a different set of resources.

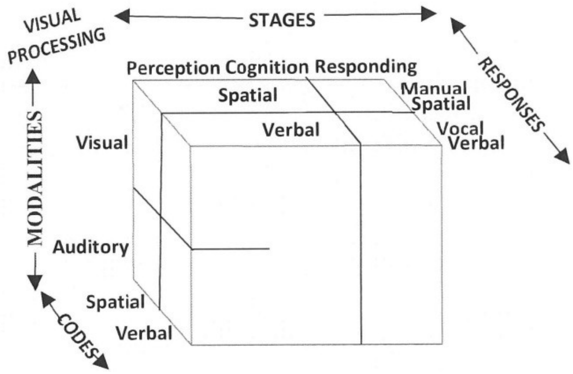

Fig. 1. Three dimensional representation of the multiple resources model, adapted from [1]

Table 1 Resources needed according the three dimensional representation

Elements	Resources
Perception-Spatial-Visual (VS)	Set 1, **Set 5**
Perception-Spatial-Auditory (AS)	Set 2, **Set 7**
Perception-Verbal-Visual (VV)	Set 3, **Set 6**
Perception-Verbal-Auditory (AV)	Set 4, **Set 8**
Cognition-Spatial (CS)	**Set 5, Set 7**
Cognition-Verbal (CV)	**Set 6, Set 8**
Manual/Spatial Response (RS)	Set 9
Vocal/Verbal Response (RV)	Set 10

The modalities dimension from [1] is a nested dimension within perception hence the distinction between visual modalities and auditory modalities only during the perception stage. The codes dimension suggests that spatial and verbal activities use different resources. The small cubes denote that spatial representation during perception or cognition shares similar resources and those resources will not be used elsewhere. Every other cube has a similar representation towards its coordinates. The table 1 represents the resources used in the three dimensional representation without taking into account the visual channels dimension (Focal/Ambient).

In the Table 1, Perception-Spatial-Visual means a perception stage requiring a vision and coding spatial information, like looking at a map. All the four first elements of table 1 deal with the perception stage. VS and VV both uses the vision.

AV and AS both use the audition. VS and AS use the same type of coding (Spatial) whereas VV and AV use a verbal coding. In the cognition stage and response stage, we distinguish only two types by stage. CS is cognition involving a spatial representation. CV is cognition involving a verbal representation. RS is a response involving space, like a gesture. RV is a verbal response.

The resources involved by CS (Cognitive-Spatial), like performing a rotation of a 3D object using cognition, are shared with VS/AS resources (they all involve spatial coding) those resources are Set5 and Set7. Because visual and auditory modalities do not appear to share resources, the shared resources between CS and VS, and the shared resources between CS and AS are different, denoted respectively Set5 and Set7. The same rule applies to the shared resources between CV and VV and the shared resources between CV and AV.

Although responses and perception/cognition are not sharing resources, in [1] a computational multiple resources model is presented by the author where he describes all the dimensions sharing a minimum of resources. From this computational model, it can be understood that although the author says that two channels appear to not share any resources does not mean that a minimum of resources is not shared but rather they interfere less with each other. Another aspect worth mentioning is that on top of the minimum of resources shared between the different elements of the cube, other resources are shared between each added dimension of overlapping resources, for example (Cognition, Spatial) and (Manual, Spatial) will share another amount of resources because they use similar coding (Spatial).

V. Scherer's emotional model

Scherer's theory belongs to the appraisal tradition and it is the most recent and the most elaborate appraisal theory to impact research in affective computing [13]. The appraisal tradition is a predominant force among the different existing families of psychological models of emotions [13].

Scherer's theory describes the emotional process as a set of five components or processes. These components are: a cognitive component whose tasks are the evaluation of events and object, a peripheral efference component who acts as a system regulator, a motivational component prepares and directs actions, a motor expression component communicates reaction and behavioural intention, and a subjective feeling component monitors the internal state of the organism- environment interaction.

Scherer uses SECs (Stimulus Evaluation Check) to determine what type of emotion is experienced at a particular moment. He describes four types of SECs as follows:

Relevance detection: [2] points out that the organism needs to scan the external and internal stimulus input constantly in order to check whether a particular situation requires attention deployment, further information processing and adaptive reactions. This check will assess if a situation is relevant enough to require more attention and relevant processing.

Implication assessment: this check measures to what extent a situation can endanger an individual or meets his goals/needs.

Coping potential determination: Coping is the ability of an individual to deal with a situation. Scherer [2] implies that coping does not necessarily mean that the individual is able to reach his original goal but it is also possible for the individual to resign himself from a situation beyond his control. As an example a student who fails his exam might feel able to cope with the situation because he thinks that changing his orientation will be more successful for him.

Normative significance evaluation: This check is to measure how an action is evaluated against the social norms of an individual. Scherer [2] uses two checks to produce the normative significance evaluation.

The relationship between the SECs and the five components is that the modification of these components are triggered by the SECs output. After each SEC evaluation, a change on the different components occurs. Changes in one component can trigger changes on other components. Changes in feelings can lead to reappraisal. The appraisal process is not only sequential; one event can lead to many cycles, sometimes to correct the appraisal values.

VI. A general emotional model using an attention theory

Most computational emotional models use a sequential paradigm in processing the information flow between the different components of the model. The idea behind using Wicken's theory is to allow a parallel processing of the information. Each component of the model can work at any time and does not need to block any other component from working before completing a task. Such architecture is justified by the previously introduced multiple resources theory [1] where the prediction of workload success is emphasized. In this theory, perception, cognition and responses can be shared among tasks and thus it is possible to assign them to a number of concurrent tasks in parallel. The proposed model is built with the aim of simulating emotions associated with events occurring at the same time and might need many cognition and action phases. The architecture of the model is presented in figure 2. The different components of the architecture are described as follows:

A. Perceptions

The perception component is responsible for transforming events from the external environment into information that can be stored in the working memory. Perception is controlled by the attention regulator. Two senses are associated with perceptions; the sight and the audition. Information is continuously acquired and depending on the attention regulator is stored in the working memory. The perception is controlled using either a top down approach or a bottom-up approach. A top-down perception is triggered when a concern requires attention such as goals or avoiding an outcome. A bottom-up perception is triggered when an event with a high valence is observed in the external environment such as hearing a loud sound.

B. Appraisal

The appraisal component is responsible for evaluating an external event. The used psychological model is Scherer's model. In this paper, details about how Scherer's model is implemented and interpreted are not discussed. Variables are determined in an environment. Those variables are converted in two variables; **Control** and **Valence.**

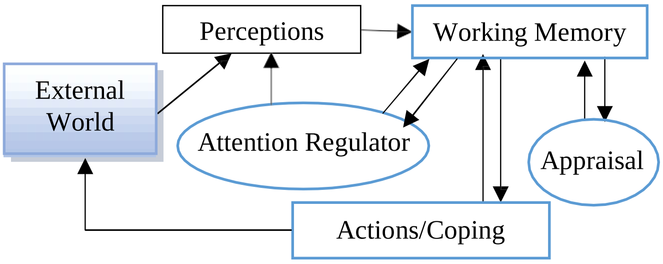

Fig. 2. Architecture of the general model

Those two variables are mapped against the Geneva Emotional Wheel [14] to label the experienced emotion. The Geneva wheel is a representation of emotion labels in a two dimensional space (Control and Valence).

C. Working Memory

Working memory is a type of memory associated with short term memory. Attending to a situation requires the working memory to build a mental representation of this situation.

D. Attention Regulator

The attention regulator is the coordinator of the system and is the main contribution of this work. It assigns the different resources to tasks depending on the situation and the importance of tasks. Multiple resources theory is used to determine conflicting tasks. Resources are allocated on demand by tasks that are related to the concerns of an agent. The considered resources are derived from table 1. This common resources are used in [1].

The attention regulator picks the potential tasks and computes their urgency/importance according to the associated goals/concerns. A sorted list of urgent/important tasks is dressed. The attention regulator will then load the most urgent/important task in the working memory and allocate the needed resources to it. If there are enough available resources, other tasks might be loaded to be executed. The resources could be at any level (Perception, cognition and responses). As an example, a person driving a car wants to arrive on time to watch his favourite TV program. This goal is the most urgent amongst the other goals. Visual- spatial resources and manual/spatial response resources will be allocated to meet this goal (driving efficiently to arrive on time). Other tasks interfering with this one in term of resources will be ignored if their urgency/importance is not comparable to the attended task and the available resources do not allow their execution. If another task more urgent/important as the attended ones is considered then a resource sharing policy is activated where less important tasks will have their resources freed if required. During the execution of tasks related to a goal involving resources allocation, a bottom-up environment scan need to be performed to detect external events. If the processed stimulus can make a task more urgent/important, than this task is brought into attention and can allocate resources.

Let's consider the previous example of the driver. While driving an accident occurs in front of the driver. The driver is now facing a threat of getting caught in the accident. An important goal which is the safety of the organism arises and at the same time this goal is more urgent/important than the attended one. If the available resources will not satisfy attending to both tasks then the attention regulator will allocate all the required resources to the later task (the resources of the former task will be freed).

E. Action/Coping

Actions and coping are modifications executed by an individual to the environment to meet one of his/her goals or to avoid a situation. Actions cannot generally be executed at the same time if they involve the same type of resources (Manual/Spatial or Vocal/Verbal). Wicken's theory also tells us that perception/cognition can be executed at the same time with a response thus we will be able to execute responses and perception/cognition based tasks at the same time. A conflict management strategy will be discussed in the following section.

VII. Resources allocation strategy

Resources are limited and any living beings cannot attend to too many situations at the same time. A simulation needs to know to what extent two situations can be attended to simultaneously. Besides that, it is not easy to determine all the types of resources involved. Studies only give us if two tasks executed at same time may interfere with each other or not but do not give us the exact amount of resources and the types needed by each task.

If an individual requires attending to two situations because they involve the same level of urgency than a conflict computation mechanism is triggered. The conflict management can determine two cases defined as follows:

- The two situations have a low level of conflict, which suggest that the two situations can be attended to at the same time.
- The two situations have a high level of conflict. In such a case, only one situation can be attended to at a time. The situation associated with the more important goal and more urgent will be prioritised. Abandoning the lower priority goal may trigger an emotion.

To compute whether or not two situations can be attended to at the same time, a conflict matrix from [1] will be used. This matrix addresses the conflict in resources' demand by the elements of the three primary dimensions of the multiple resources model. Table 2 gives an illustration of the 'conflict matrix'.

In the conflict matrix, conflict values are assigned to resources allocations if different phases of two tasks (Task A and Task B) are executed at the same time. If Task A and Task B require both a visual spatial perception at the same time, then during that phase the conflict value is 0.8 (from the matrix). If both tasks require at the same time a verbal response then the conflict value is 1.0, which means that we cannot produce two different verbal responses at the same time. Those values may not be the same in all cases; for example performing a visual-spatial operation on two distinct objects that are close to each other may require less effort and interference than if they were far from each other [1].

Table 2 Conflict Matrix [1]

		Task A Resources							
		Perceptual				Cognitive		Response	
		VS	VV	AS	AV	CS	CV	RS	RV
Task B Resources	VS	0.8	0.6	0.6	0.4	0.7	0.5	0.4	0.2
	VV		0.8	0.4	0.6	0.5	0.7	0.2	0.4
	AS			0.8	0.4	0.7	0.5	0.4	0.2
	AV				0.8	0.5	0.7	0.2	0.4
	CS					0.8	0.6	0.6	0.4
	CV						0.8	0.4	0.6
	RS							0.8	0.6
	RV								1.0

The different labels in Table 2 are VS (Visual Spatial), VV (Visual Verbal), AS (Auditory Spatial), AV (Auditory Verbal), CS (Cognitive Spatial), CV (Cognitive Verbal), RS (Response Spatial), and RV (Response Verbal). Because the exact involved body/mind resources in each stage are not known, the 'Conflict Matrix' will be used to determine whether two situations can be attended to at the same time or not.

The 'Conflict Matrix' gives us how much two tasks can interfere with each other if two phases of those tasks are executed at the same time. However, to compute the interference, it is useful to include in the computation the amount of resources needed in each phase by the tasks.

A vector representing the resources available will be used. This vector named ‘AR’ vector is an eight-dimensional vector. Each cell of the vector represents the initial availability of the resources involved by one of the eight elements (VS,VV,AS,AV,CS,CV,RS,RV). A task will be represented by a similar eight-dimensional vector TR_{Task}, describing the resources needed for its correct execution. Since most elements within a task do not interfere with each other in most cases because of their sequential requirement [1] , we assume that there is no interference between elements within a particular task. When a new task T1 requires attention, the AR vector will be updated according to the following formula:

$$AR[i] = AR[i] - MAX_{j=1}^{8}(shr(i, j) \cdot TR_{T1}[j] + intr(i, j)) \ , \ i \in [1,8]$$

where $intr(i, j)$ is the interference between the element at the position i and the element at the position j, taken from Table 2 and $shr(i, j)$ is the sharing coefficient; it determines the shared resources between the element at position i and the element at position j. $shr(i, j) = \begin{cases} intr(i,j) + 0.2 & if\ i = j \\ intr(i,j) & otherwise \end{cases}$

The formula used to update the vector AR is explained by computing the shared resources required by an element of the TR_{T1} vector and an element of the AR vector. This is computed by $shr(i, j) \cdot TR_{T1}[j]$. Then, $intr(i, j)$ is added to include the interference. Each cell of AR will represent how much resources are available for each associated element. The maximum is taken in order to take only into account the worst cases.

Allocation algorithm:

```
AR available resources vector, TR the resources vector of a task R, ARtmp Vector, float max=0;
Copy AR values into ARtmp
For i=1..8
  For j=1..8
    If max<shr(i, j) · TR[j] + intr(i, j)
        max= shr(i, j) · TR[j] + intr(i, j)
   End for
   ARtmp[i]=ARtmp[i]-max
   max=0;
 If ARtmp[i]<0 return false
End for
Copy ARtmp values into AR
Return true
```

Note: intr(i,j)=0 if there is no task intended when the task R is examined

If a task causes AR[i]<0, $i \in [1,8]$ then the task is not executed and will go to a waiting list. The tasks in the waiting list will have their urgency and goal importance updated constantly.

The following is an example showing a scenario:

T1 is driving a car from point A to point B. This is a task defined by the vector (2,0.5,0,0,0,0,0,1.5). This task needs to be attended to by a person whose AR vector is (3,3,2.5,3,3,3,2.5,2). The person is attending to task T1. Applying the allocation algorithm updates AR to (1,1.8,1.3,2.2,1.6,2,1,1.1). This means that T1 can be attended to by that person. After that, a task T2 which is listening to the radio defined as (0,0,0,1,0,0,0,0) needs to be attended to. The Allocation algorithm updates AR to (0.2,0.6,0.5,0.4,0.6,0.6,0.2,0.1) which means that T2 can be attended to while attending to T1.

The driver switch off the radio and T2 resources are freed. AR is updated to (1,1.8,1.3,2.2,1.6,2,1,1.1) and another task T3 is brought into attention. T3 is to make a phone call. It is defined by the vector (0,0,0,1.5,0,0,1,1.5). If the driver attempts to execute T3 while executing T1, which is illegal, the allocation algorithm will update the vector AR to (0,0.3,0.3,-0.1,0.35,0.25,-0.8,-1.4). Several values of the AR vector are negative; this means that T1 and T3 cannot be executed at the same time. While the direct link to emotion was not shown in this example, T1, T2 and T3 can either be related to a goal to reach/avoid an emotional state or to emotional coping strategies.

VIII. New bottom-up tasks

If a bottom-up task arises (like a light flashing suddenly or upon the hearing of a loud sound), the attention is directed to it. Those tasks are mainly perceptive and will interrupt attention and take the required perceptive resources then their urgency and goal importance will be evaluated. After that, this task will be treated like any other task.

IX. Complex tasks

Some tasks require two or more phases in parallel to be executed. Like taking notes while a presenter is giving a talk. In one phase the user is required to attend to the speech and in another phase he/she is required to write down his/her interpretation of the speech. This kind of composed tasks can be coded in two ways. The first way is to create two eight- dimensional vectors similar to a regular tasks vector and take them like two concurrent tasks being executed at the same time. This way is suggested because there is some interference between those two tasks unlike a standard task where there is no interference in between its elements. In case of two sub- tasks with no interference between them or the user know how to execute them without any interference, then it is better to represent them as a single task with only one vector of resources.

Some tasks require more than one phase. Each phase may involve different resources. Those types of tasks can be represented by a chain of resource vectors. The vectors do not interfere between each other since they are executed sequentially. Combining sequential sub-tasks and parallel sub- tasks in one task is possible.

X. Conclusions and future work

In this work, we presented a technique that allows multitasking when simulating emotions by directing attention. The used emotional model is Scherer's model where attention is required at the earliest stages. Using Wicken's multiple resources model allowed us to implement a mechanism to control attention in a dynamic environment. The vector representing tasks is simple enough for the designer as it does not represent tasks by precise body and mind resources but it rather uses elements representing groups of resources involved by them (VS,VV,AS,AV,CS,CV, RS,RV). This representation is able to give a correct enough tasks coding. So, in our opinion, this coding gives an acceptable compromise between tasks representation and simplicity. Although the original aim is emotion simulation, the presented technique can be used for other types of simulation involving multitasking and cognition.

In this method the maximum interference was taken as suggested by the formula but in reality, individual differences account when executing two concurrent tasks. Like an experienced driver might better share resources between two tasks than an inexperienced one. The interaction between the affective state and the available resources should be examined where experiencing some types of emotions can reduce the amount of resources available (arousal influence is an example). Another idea is to study whether changes in subjective feelings require the allocation of resources and then interfere when executing a task.

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