Designing interactive systems that augment creativity by regulating task-evoked emotions

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Abstract
Emotions can augment or diminish creativity. This presents an opportunity for designing interactive systems that augment creativity. However, how to design such systems is still an open problem. In this position paper, this problem is addressed theoretically. Systems should regulate, rather than cause, emotional responses during the idea generation process; which can be achieved by embedding features of the emotion components that underlie the emotion-creativity link directly into the user-system interactions. Two case studies are discussed that demonstrate successful regulation via technology of a link between positive emotion and generating original ideas. Although these verify the theory's usefulness, further debate needs to uncover how to make practical application possible.

Author Keywords
Augmented creativity; Design; Emotion regulation.

Introduction
Creativity is often seen as the new smart, a valuable human skill that helps innovation to thrive [1]. Emotions can augment of diminish creative idea generation [2]. This presents interesting possibilities for designers of interactive systems that augment

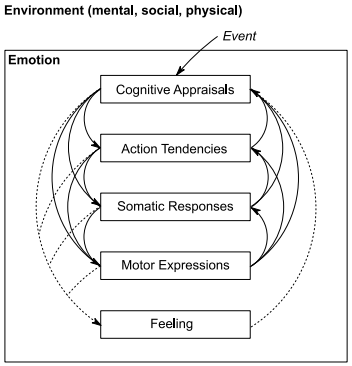

Figure 1: Emotion components and their feedforward and feedback relationships. Model is based on [5, 6].

creativity. How to design such systems is however, still an unanswered question [3]. Despite this, research on the development of interactive systems that attempt to utilise the emotion-creativity link is now emerging increasingly [4]. To support this, this position paper presents a theory that can inform designers of interactive systems that augment individual creativity, on how to effectively utilise the emotion-creativity link.

The emotion-creativity link

Emotions are adaptive responses to the environment that support a person's wellbeing [5]. An emotional response is typically caused by the appraisal of an event (e.g. this idea is creative), which feeds forward into changes in action tendencies (e.g. goal-directed approach), somatic and endocrine responses (e.g. dopamine release), motor expressions (e.g. a smile), and feelings, the component changes that enter awareness (e.g. feeling happy). Changes in each component feeds back to function as a disposition that maintains the emotional response [6]. See *Figure 1*.

Creative idea generation can be defined as the creation of original and effective ideas [7]. It is a process where concepts are combined into ideas [8]. Appraising the potential of a conceptual combination for creativity moves the process forward (e.g. the likelihood that concepts yield original ideas). Appraising the actual creativity of an idea may drive the process backward (e.g. to select new concepts for idea generation), or maintain it (e.g. to generate multiple ideas using the same concepts) [8].

Emotions can augment creative idea generation when the effect of an emotion on the execution of the idea generation process supports generating original and effective ideas [3]. This *emotion-creativity link* can be explained by associations of emotions with cognitive flexibility, the ease with which one switches thought processes, and cognitive stability, the ease with which ongoing processes can be maintained [2].

Positive emotion, e.g., augments generating original ideas [3]. Positive emotions are caused when an event is appraised as conducive to a task [9]. If a conceptual combination has a high potential for originality, cognitive flexibility increases to enable switching between conceptual combination and idea generation, causing positive emotion. This increases the amount and variety of ideas generated, which increases the likelihood that an idea is original [2]. If an idea is appraised as original, cognitive stability increases to support generating more ideas using the same concepts, also causing positive emotion. As positive emotions feed forward, associated changes in the emotion components, feedback helps to maintain the positive emotion [5, 6]. This results in a disposition to exploit original ideas, and increases the switching between conceptual combination and idea generation [2, 3]; and so, people generate more, more diverse, and more original ideas [9]. Positive emotion can therefore augment the generation of original ideas.

It can thus be argued that the emotion-creativity link can be leveraged to design interactive systems that augment creativity.

Emotion causation versus regulation

Designing interactive systems that utilise the emotion-creativity link presents an interesting *challenge*. Many interactive systems exist that can cause emotion [10]. For example, social signals have been used to cause

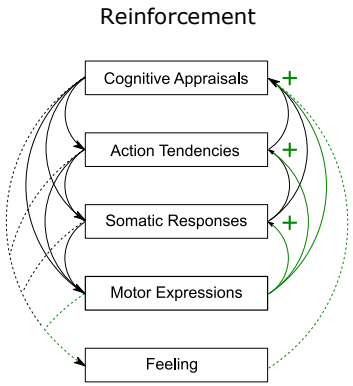

Figure 2: Emotion regulation can be achieved via suppression (top) and reinforcement (bottom), of the feedback relationships among emotion components. Figures show reinforcement and suppression of all components, but regulation can be achieved via individual components as well. Models are based on [5, 6].

emotion [11], as have background stimuli [12] and music [13]. However, there is one major limitation that makes approaches such as these ineffective for designing systems that use the emotion-creativity link.

Emotions are caused by appraisals of the user's environment [5]. This environment can be external [5], which enables most technologies to use stimuli external to the idea generation to elicit emotion [14]. However, the events that elicit emotion during creative idea generation happen largely within the user's *mental environment* because they are elicited by appraisals of the idea generation process [4]. Therefore, causing emotion with stimuli that are unrelated to both the creative idea generation process and the emotions it elicits, is unlikely to augment creativity. This due to: *Overriding effects:* Causing emotion with stimuli prior to idea generation affects creativity only for a short time. Emotions caused by the idea generation process itself quickly overrides any effects of previously elicited emotions on creativity [15]; and *Limited attention:* Causing emotion with stimuli unrelated to idea generation does not capture attention (users focus on their mental environment), cf. [12], or distract from it, possibly diminishing creativity, cf. [16].

Given these challenges it is unlikely that designing interactive systems to cause emotion in ways unrelated to the idea generation process can utilise the emotion-creativity link. Rather, interactive systems should *regulate* the emotions elicited during idea generation.

Designing interactive systems to regulate emotion

Emotion regulation is the modulation of an emotion (*Figure 2*) [6]. Emotion diminishes when suppressing changes in its components, preventing the feedback that maintains it. Emotion augments when reinforcing component changes amplifying the feedback that maintains it. Interactive systems can regulate emotions elicited during idea generation by embedding features of emotion components directly into the user-system *interactions* [17]. This can enable: I) *Suppression:* Interactions can be designed to suppress emotions that diminish, and not suppress emotions that augment creativity; and II) *Reinforcement:* Interactions can be designed to not reinforce emotions that diminish, and reinforce emotions that augment creativity.

How interactive systems can effectively achieve emotion regulation during idea generation is an open problem. As a starting point, I propose the following:

- *Appraisals* that cause emotion can be re-appraised by providing manipulated informational feedback about events during idea generation, e.g. feedback to re-appraise the originality of an idea [4, 18];
- *Action tendencies* can regulate emotion via goal-directed motivational feedback on how the idea generation process is executed, e.g. feedback to suggest avoiding conceptual combination [19].
- *Somatic responses* can regulate emotion by using (fake) biofeedback to influence interoceptive awareness, e.g. perceiving pupil size changes that indicate cognitive flexibility and focus [20];
- *Motor expressions* can regulate emotion when embedded in the physical user-system interactions, e.g. via gesture control that embeds features of emotional expressions [9, 17].

Two tested prototypes that were previously designed based on the presented theory illustrate its potential.

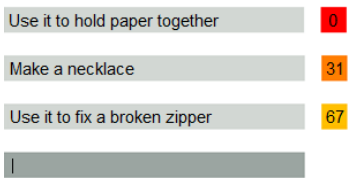

Figure 3: Designing for regulation via re-appraisal. Interface presents manipulated scores of the originality of user generated ideas. Image from [18]

Figure 4: Designing for regulation via motor expressions. Part of the positive gesture (top) and the negative gesture (bottom). Images from [9].

Case I: Designing for regulation via re-appraisal
This prototype was designed to test whether *re-appraisal* could be used to augment generating original ideas, by regulating positive emotion [4, 18]. The system estimates the originality of an idea based on an AI model. When used during idea generation the system provides originality scores in real-time (*Figure 3*). This enables re-appraisal of the originality of an idea. The system increases or decreases the originality scores to deviate from the typically appraised originality of the user's ideas, to I) elicit the re-appraisal that an idea is more original than initially appraised (*reinforcement*), or II) the re-appraisal that an idea is worse than appraised (*suppression*), Experimental results showed that maintaining positive emotions augmented the generation of original ideas [4, 18].

Case II: Designing for regulation via motor expressions
This prototype was designed to test whether *motor expression* could be used to augment generating original ideas, by regulating positive emotion [9, 17]. Features of expressions that associate with positive and negative emotions we used to design gestures that are used to record ideas into a Dictaphone during a brainstorm (*Figure 4*). The gestures were captured using skeleton tracking and acoustic myography sensors [21]. When generating an idea, users directly recorded it using either an instructed positive or negative gesture. We assumed that when positive emotions were elicited, the positive gestures would maintain the positive emotion (*reinforcement*), and the negative gestures would diminish it (*suppression*), and vice versa for negative emotions. The results indeed suggested that emotion regulation took place, with using the positive, rather than the negative gestures, augmenting the generation of original ideas [9, 17].

Discussion

In this position paper, a novel theory is presented that can inform designing interactive systems that *augment creativity* by *regulating task-evoked emotions*. It is proposed that this can be done by embedding features of the components of emotions that augment creativity directly into the user-system interactions: by designing for re-appraisal [4, 18], guiding action tendencies, cf. [19], modulating somatic responses, cf. [20], and embedding features of motor expressions in the physical interactions users have with a system [9, 17].

The theory has partly been verified by developing and testing two prototypes. Both designing for emotion regulation via *re-appraisal* [4, 18], and designing for regulation via *motor expressions* [9, 17], augmented creativity under laboratory conditions. Although these initial studies support the developed theory, further debate is necessary to answer questions that will enable it to become useful in practice. As a starting point for this debate I propose the following questions:

I) What (other) emotion-creativity links are desirable to make use of?
II) What (other) parts of the creative process can be augmented using emotion-creativity links?
III) What (other) ways are there to design interactive systems that achieve emotion regulation?
IV) What is needed to make this theory work in practice rather than under laboratory conditions?

Further *debate* around these questions will advance this theory so that it can be used for designing interactive systems that augment creativity by regulating task-evoked emotions in practice.

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