Hacking into the emotion-creativity link

Two new approaches to interactive systems that influence the relationship between emotion and creativity

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Submitted for the degree of Doctor of Philosophy in Creativity Science

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06/2016

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Acknowledgements

This thesis owes a lot to the kind support of many people. I am especially grateful to my supervisor, Dr Sara Jones. Aside from her valuable input during the development of the ideas underlying my studies, tuition, and support, she has been a great help in developing my academic writing skills. I am also indebted to Professor Philip Corr, who has been a great help discussing the theoretical and methodological underpinnings of my studies, to Srikanth Cherla, for supporting the development of the interactive system described in chapter 5, and to Professor Neil Maiden, for his insightful comments on the research done throughout my studies. Personal gratitude is also due to Graham Dove, James Lockerbie, Mobina Nouri, and the many others at the Centre for Creativity in Professional Practice and the Centre for Human Computer Interaction Design for our many discussions, which have undoubtedly shaped the research presented in this thesis. I would also like to point out that the research presented in this thesis would not have been possible without the time invested by the many people who participated in my studies, and Stuart Scott, who has been a great help providing the space and equipment that made doing this research possible. Finally, I would like to thank Judith and Edin, for the joy they bring into my life.

Declaration

The work described in this thesis is based on research carried out at the Centre for Creativity in Professional Practice, City University London, London, United Kingdom. No part of this thesis has been submitted elsewhere for any other degree or qualification. All work is my own, unless stated otherwise. Throughout this thesis I will refer to my work as our work, and to I as we, as a courtesy to the many people that helped shape the research presented in this thesis.

Alwin de Rooij　　　　　　　　　　　　Date

Abstract

Emotions can influence creative thinking. The ability of people to have the emotions that augment creativity can therefore help them to achieve higher creative task performance. How to design interactive systems that can effectively make use of this potential is, however, still an unanswered question. To explore possible answers to this question we have developed two novel approaches to interactive systems that can be used to effectively hack into the emotion-creativity link.

One approach we developed enables a system to hack into the function of motor expressions in emotion regulation, in order to regulate the emotions that happen spontaneously during a creative task. We demonstrate that embodied interactions designed based on motor expressions, while used to interact with a system, can influence an intended emotion, and thereby influence the relationship between emotion and creativity.

The second approach that we developed enables a system to hack into the cognitive appraisal processes that help cause emotion during a creative task. We demonstrate that believable computer generated feedback about the originality of a user's own ideas, can be manipulated to help cause an intended emotion, determine its intensity, and thereby also influence the relationship between emotion and creativity.

The contribution of this thesis is the development of two novel approaches to interactive systems that aim to influence the emotion-creativity link and in particular the explication of the mechanisms underlying these approaches. The studies form a novel contribution to both interactive systems research and the creativity sciences.

1. Introduction

Emotions can influence how people think and act in ways that augment or diminish creative thinking. For instance, when people experience positive emotions, the flexibility with which information is made available during the generation of ideas is increased, which can help people to come up with more original ideas. The ability to have the emotions that augment creativity during activities that can benefit from creative thinking, can therefore help people to achieve higher creative task performance. This presents an opportunity for designers of technologies that aim to augment creativity, to develop systems that influence emotion, and via emotion, augment creativity. Until now, however, research about ways in which interactive systems can be designed to make use of the emotion-creativity link, has been limited. This is surprising, because creativity is often seen as the new smart, a sought after skill that helps well-being, innovation, and culture thrive.

1.1 Research challenges

In this thesis we develop two new approaches to interactive systems that can make use of the emotion-creativity link, with the aim to help people to get more out of their own creative capabilities. In particular, we focus on explicating the mechanisms underlying the proposed approaches. The development of an interactive system that influences emotion to augment creativity requires solving two challenges.

One challenge is to obtain knowledge about the aspects of emotion that augment or inhibit creativity.

Emotions have been defined as responses to events that help adapt the way we think and act in support of our own and other's wellbeing (Campos et al., 2004; Kappas, 2011; Scherer, 2009). Emotions consist of changes in a number of emotion components, which can be used to explain the adaptive changes that associate with emotion, and include: the cognitive appraisal of events (e.g. this is appealing); action tendencies that prepare and guide taking action (e.g. a tendency to approach); somatic and neuroendocrine responses that support and guide evaluation and action (e.g. dopamine release in reward pathways); motor expressions that make up the physical actions that occur in response to an event (e.g. smiling and approaching movements); and feelings (also often referred to in the literature as affect (Panksepp, 2000)), the aspects of the mentioned emotion components that can be subjectively experienced (e.g. feeling joyous) (Scherer, 2009). See Figure 1.

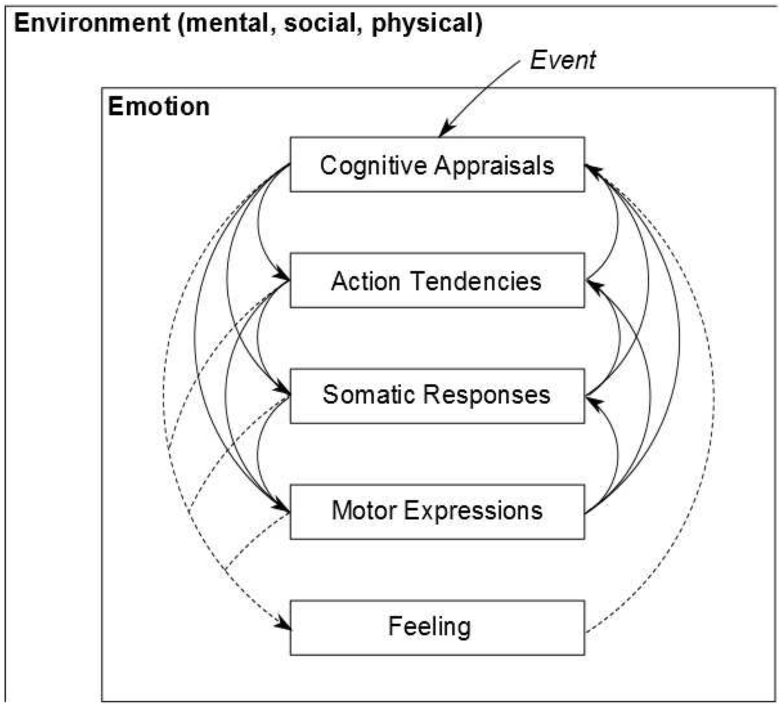

Figure 1 Schematic of emotion regulation and causation. An event in the environment causes emotion via cognitive appraisal processes, which feeds forward to drive changes in action tendencies, somatic and neuro-endocrine responses, motor expressions, and feelings. These emotion components feed back into each other, which enables regulation of an emotion. Feelings are an exception, which due to its dependency on awareness, influences cognitive appraisal processes only (after Moors, 2013; Scherer, 2009; Schwartz & Clore, 2007).

Creativity has been defined as the development of ideas, insights, or solutions that are both original and effective (Runco & Jaeger, 2012). A number of components have been hypothesized to make up the factors that enable creativity, which include: the *creative process*, a distinct set of information processing steps that people cycle through when engaging in a creative task, e.g. combining concepts enables idea generation, generated ideas are evaluated based on their originality and effectiveness (Mumford et al., 2012); and, *motivation*, the arousal, direction, and persistence of someone's behaviour (Franken, 2006), which ensures that people invest sufficient resources into a creative task, to persist throughout the creative process, e.g. tasks that require creativity are often demanding, and motivation can help increase the persistence of people during those creative tasks (Collins & Amabile, 1999). See Figure 2.

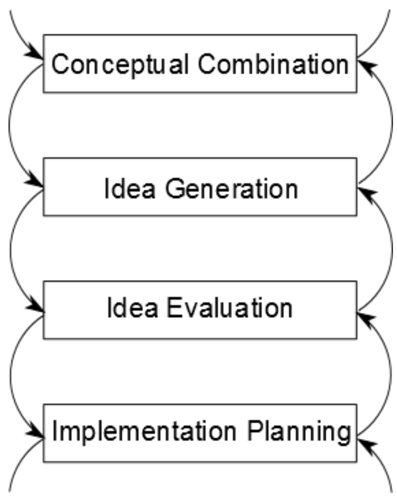

Figure 2 Schematic of part of the creative process. To enable creativity, people cycle back and forth through e.g. conceptual combination, idea generation, idea evaluation, and implementation planning. The way these steps in the creative process are executed determines creative task performance (after Mumford et al., 2012).

The relationship between *emotion and creativity* depends on the influence of the adaptive changes that are caused by emotion on the way people think and act, on the execution of the creative process and the motivational factors that enable creativity (Baas et al., 2008; Davis, 2009). This information can be obtained by reviewing empirical research from psychology about the relationship between emotion and creativity. This informs what aspects of emotion such a system should attempt to influence in order to augment creativity. Thus, the literature review in this thesis is used to take on the first research challenge.

The main challenge, however, is developing an approach to designing interactive systems that enables these systems to influence emotion, in a manner that also suits creativity. The issue is that the influence of emotion on the way people think and act depends on the nature of the events that cause emotion, and the situation in which these emotions are caused (Wilson-Mendenhall et al., 2013). For instance, using positive pictures to cause emotion during a creative task may cause positive emotions that are directed towards those pictures but do not carry over into the task (Chiew & Braver, 2014). It follows that the effectiveness of an interactive system that aims to influence emotion to augment creativity is restricted by whether the way the system influences emotion is meaningful within the context of a creative task (Gasper, 2003; Kaufmann & Vosburg, 2002).

Tasks that require creativity in particular may impose a particular set of restrictions on such interactive systems. For instance, an artificial social actor can help regulate students' emotions on a learning task because it can be made meaningful within the context of a classical student-tutor relationship (Woolf, 2009). However, for many creative tasks it is not possible to find such a role for an interactive system. For example, because creative tasks are often performed alone. In such cases the only meaningful source of emotion is often the creator's own appraisal of the mental events that occur during the task. For instance, during an idea generation task the cognitive act of combining different concepts can lead to the generation of a new idea (Mumford et al., 2012), which in turn can cause positive emotion in the person who has had that idea (cf. Akhbari Chermahini & Hommel, 2012a; Zenasni & Lubart, 2011). What here would be a meaningful way to influence emotion?

As one possible solution, we suggest that an interactive system can be designed to enable the function of motor expressions in emotion regulation. Motor expressions, the physical actions that form part of an emotion, have a reciprocal relationship with emotion (Scherer 2009). For instance, we smile when we experience a pleasant event (Ellgring & Scherer, 2007a), but experiencing a pleasant event while smiling also increases its pleasantness (Soussignan, 2002). Motor expressions may therefore be able to help regulate the emotions that are caused by the creative task itself, in such a way as to augment creative task performance (Friedman & Förster, 2002).

As a second possible solution, we suggest that an interactive system may be designed to manipulate the cognitive appraisals of the events that cause emotion during a creative task. Cognitive appraisals, the subjective evaluations of emotion-relevant events, largely determines if and how an emotional response unfolds (Moors, 2013). For instance, positive rather than negative emotions are typically caused when an event is appraised as conducive rather than obstructive to your goals (Scherer, 2009). The particular cognitive appraisals that help cause emotion during a creative task may therefore be used to cause the emotions that augment creative task performance (cf. Akhbari Chermahini & Hommel, 2012a; Zenasni & Lubart, 2011).

This is the basis of the way we address these research challenges in the work presented in this thesis.

1.2 Research questions and objectives

These challenges translate into two research questions about whether or not our two new approaches to interactive systems can effectively influence the emotion-creativity link. Each research question will be supported by two research objectives.

RQ1: Can the function of motor expressions in emotion regulation be used to develop an effective approach to interactive systems that influence the emotion-creativity link?

> *O1: Demonstrate that imposing motor expressions can help regulate emotion and augment creativity.*

The objective here is to experimentally demonstrate that imposing motor expressions that associate with positive emotion and approaching action tendencies, rather than negative emotions and avoiding action tendencies, can augment creativity; and that incompatibility rather than congruence between a motor expression and an emotion can also augment creativity during idea generation. This is to justify using motor expressions to regulate emotion in further research in an interactive systems context. Study 1 is designed to achieve this research objective (chapter 4). Note that this study does not test the function of motor expressions within the context of interactive systems yet. Rather, the study is aimed at exploring ways in which motor expressions can influence the emotion-creativity link, which aims to justify further exploration in an interactive systems context, and which is the subject of later studies.

O2: Demonstrate that an interactive system can be designed to use the function of motor expressions in emotion regulation to help people perform better on idea generation and insight problem solving tasks that require creativity.

The objective here is to experimentally demonstrate that embodied interactions (arm gestures) designed based on motor expressions that associate with positive emotion and approaching action tendencies, rather than negative emotions and avoiding action tendencies, and used to interact with a machine, can regulate an intended positive emotion, and thereby augment creativity. Study 2 is designed to achieve this research objective (chapter 5).

RQ2: Can the cognitive appraisal processes that form part of positive and negative emotions be used to develop an effective approach to interactive systems that influence the emotion-creativity link?

> *O3: Demonstrate that an interactive system can be designed to use the function of cognitive appraisal processes in positive and negative emotion, to help people perform better on idea generation tasks that require creativity.*
>
> The objective here is to experimentally demonstrate that manipulating computer generated feedback, about the originality of a person's ideas, to be better or worse than people typically expect, can cause an intended positive or negative emotion accordingly, and thereby influence creativity during idea generation. Study 3 is designed to achieve this research objective (chapter 6).
>
> *O4: Demonstrate that an interactive system can be designed to use the function of cognitive appraisal processes in determining the intensity of positive and negative emotion, to influence the degree to which creativity is augmented or diminished.*
>
> The objective here is to experimentally demonstrate that the manipulation of computer generated feedback, about the originality of a person's ideas, to be better or worse than people typically expect, can be used to condition the expectations people have about their own ability to generate original ideas, and therefore help determine emotional intensity, and thus the degree to which emotion influences creativity. Study 4 is designed to achieve this research objective (chapter 7).

This summarizes the research questions that we will attempt to answer, and the research objectives we will attempt to achieve, in the research presented in this thesis.

1.3 Contribution

The *contribution of* the research presented in this thesis is the development of two novel approaches to interactive systems, which are designed to influence the relationship between emotion and creativity, with the goal to help people to get more out of their own creative capabilities. The contribution focuses in particular on explicating the mechanisms underlying the proposed approaches. The contribution that we intend to make is to the creativity sciences, the scientific study of creativity and innovation; and to interactive systems research, the scientific study of the interaction between people and machines.

Our studies presented in this thesis *contribute to* research on interactive systems that aim to influence emotion to augment creativity. However, as a by-product of our studies, we also claim to make novel contributions to the more general areas of interactive systems that aim to augment creativity, interactive systems that aim to influence emotion, and to theory about the emotion-creativity link. This will be discussed in detail in chapter 8.

This summarizes the contributions of the research presented in this thesis.

1.4 Scope of the thesis

Throughout our studies we will focus the capabilities of our two new approaches, on the relationship between positive and negative emotions, and creativity. This is motivated by our review of empirical research from psychology about the relationship between emotion and creativity, which suggests that positive, rather than negative, emotions augment various aspects of the creative process. This is discussed in further detail in section 2.2.

The scope of our research is further restricted to creativity during idea generation. This is motivated by the observation that different aspects of emotion influence steps in the creative process differently. As a consequence, we will focus the capabilities of our two approaches on the relationship between positive and negative emotions and creativity during idea generation. This is discussed in further detail in section 3.3.

The way in which we will enable our interactive systems to influence this relationship, is by hacking into different emotion components. In theory, many emotion components exist that could be used for this purpose. However, as we already discussed in the above sections, in this thesis we will only focus on motor expressions and cognitive appraisal processes that form part of positive and negative emotions. This is discussed in further detail in chapters 4, 5, 6, and 7.

This delimits the scope of the research that will be presented in this thesis.

1.5 Outline of the thesis

This thesis is organised in the following chapters.

Chapter 2: Literature review. Reviews the relationship between emotion and creativity, and presents a discussion of interactive systems that are designed to influence emotion, augment creativity, and influence emotion with the goal to augment creativity.

Chapter 3: Methods. This describes the general methodological approach taken, and measurement instruments used in our studies.

Chapter 4: Study 1: Motor expressions as creativity support. This describes the study designed to achieve *research objective O1*.

Chapter 5: Study 2: Hacking into the function of motor expressions in emotion regulation to augment creativity. This describes the study designed to achieve *research objective O2*.

Chapter 6: Study 3: Hacking into cognitive appraisal processes to augment creativity during idea generation. This describes the study designed to achieve *research objective O3*.

Chapter 7: Study 4: Hacking into cognitive appraisal processes to determine emotional intensity to augment creativity during idea generation. This describes the study designed to achieve *research objective O4*.

Chapter 8: Discussion. Discusses the studies with regard to the research questions and research objectives, the contributions made, and limitations of the study results, based on which we recommend several directions for future work.

Appendices:

> *Appendices A-E*: Published peer-reviewed articles
> *Appendix F*: Technical report that details technical work relevant to study 2.

1.6 Published articles

The following articles based on the research undertaken in this thesis are published and peer reviewed.

Chapter 2

de Rooij, A. & Jones, S., 2013. Mood and Creativity: An Appraisal Tendency Perspective. In *Proceedings of the 9th ACM Conference on Creativity & Cognition*. Sydney, 2013. ACM.

Chapter 4

de Rooij, A. & Jones, S., 2013. Motor Expressions as Creativity Support: Exploring the Potential for Physical Interaction. In *Proceedings of the 27th International British Computer Society Human Computer Interaction Conference*. London, 2013. British Computer Society.

de Rooij, A., 2014. Toward Emotion Regulation via Physical Interaction. In *Companion volume of the Proceedings of the 19th International Conference on Intelligent User Interfaces*. Haifa, 2014. ACM.

Chapter 5

de Rooij, A. & Jones, S., 2015. (E)Motion and Creativity: Hacking the Function of Motor Expressions in Emotion Regulation to Augment Creativity. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*. Stanford, CA, 2015. ACM.

Chapter 6

de Rooij, A., Corr, P., & Jones, S., 2015. Emotion and Creativity: Hacking into Cognitive Appraisal Processes to Augment Creative Ideation. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition*. Glasgow, 2015. ACM.

These articles can be found in *Appendices A-E*.

2. Literature review

A paper that presents some early theoretical ideas about the emotion-creativity link was presented at the poster session of the 9th ACM Conference on Creativity and Cognition, June 2013, Sydney, Australia. This paper is included in Appendix A.

2.1 Introduction

In this literature review we will present empirical research from psychology on the relationship between creativity and emotion. This informs what aspects of emotion should be influenced by an interactive system if it is to augment creativity. We also present an overview of interactive systems that are designed to influence emotion, augment creativity, and influence emotion to augment creativity. This serves the purpose of positioning the research we develop in this thesis within the context of interactive systems, but also of exposing possible limitations to the effectiveness of previous approaches.

2.2 Emotion and creativity

To inform the conception of an interactive system that aims to influence emotion with the goal of augmenting creativity, one needs to know what aspects of emotion influence creativity. These aspects of emotion then become the focus of the capabilities of such an interactive system, with which it aims to influence the emotion-creativity link.

Emotion models differ in the way the relationships between the emotion components are organised, what emotion components form part of emotion, and generally how emotion is conceptualised (Moors, 2009; 2013; Shuman & Scherer, 2015). In this thesis we wish to emphasise that the emotion model that is used as a basis for this review and our subsequent studies is the componential model (also referred to as the component process model (Scherer, 2009)). We will discuss how this model relates to the causation and regulation of emotion. We will emphasise the roles of appraisal processes and motor expressions in these because they embody the mechanisms that underlie the approaches developed in this thesis.

Following the componential perspective on emotion as developed by Scherer (2009) we assume that there exists a reciprocal relationship among the emotion components. Here, a typical emotional response is assumed to be caused by events that are appraised in a manner that has some bearing on the individual's or someone else's wellbeing (Scherer, 2009). Appraisal processes feed forward into the (other) emotion components to drive changes in the way people think and act, in order to form an adaptive response toward the events that initially trigger the appraisal processes (e.g. a smile caused by the appraisal that an event is conducive to the individual's goals). The componential model emphasises the importance of appraisals of events from the individual's environment in the emergence of emotional responses. See Figure 1.

The componential perspective also suggests that changes in the emotion components also feed back into the (other) emotion components, and include both positive (enhancing) and negative (suppressing) feedback loops (Moors; 2013; Scherer, 2009). Therefore, the model assumes that changes in the emotion components serve regulatory and dispositional functions (Gross, 1998). That is, changes in the emotion components can enhance (positive feedback) or be suppressive (negative feedback) to an emerging emotional response. For instance, regarding motor expressions, smiling increases the funniness people attribute to a comic (appraisal) (Strack et al., 1988); arm flexion increases positive feelings when it suggests pulling something towards you that you desire (action tendencies) (Centerbar et al., 2006); smiling is shown to activate dopaminergic pathways in the brain (somatic and neuroendocrine) (Wiswede et al., 2009); and mimicking emotion expressions increases the consciously experienced feelings of these same emotions (Flack, 2006; Flack et al., 1999). The componential model emphasises the role of individual emotion components in the regulation of an emerging response.

Feed forward and feedback links between the emotion components also indicate that there can occur bottom-up effects of changes in the emotion components on an emotional response (Scherer, 2009). That is, changes in the emotion components that associate with particular emotions can drive changes in the other emotion components accordingly, which can possibly drive changes in the way people think and act without the occurrence of an emotion-relevant event (Carney et al., 2015). Recent work suggests that expanding (vs. constricting) postures increase risk tolerance (appraisal) (Carney et al., 2010), cortisol and testosterone levels (somatic and neuroendocrine component) (Carney et al., 2010), the feelings of power (Carney et al., 2010; Riskind & Gotay, 1989), and generally influences (adaptive) behaviours accordingly without the occurrence of an initial event as a top-down cause of emotion (Carney et al., 2015; Cuddy et al., 2015; Yap et al., 2013). Even though one could argue that the componential model could accommodate such bottom-up effects, there are also reasons for not emphasising such bottom-up effects in our studies (see below).

In this thesis we emphasise the importance of events in causing emotion, the role of appraisals therein (chapters 6 and 7) and the subsequent functioning of motor expressions as a way to regulate emotions (chapters 4 and 5). This is in part due to the large amount of evidence that exists on the role of events and appraisal processes in causing emotion (see for instance Moors; Roseman, 2004; Scherer, 2009; Siemer, 2007 for overviews); and due to the large amount of evidence that exists about the function of motor expressions (and other emotion components) in emotion regulation (see for instance Critchley & Nagai, 2012; Gross, 1998; Pfaf et al., 2014; Price & Harmon-Jones, 2015 for overviews). We will further elaborate theoretically on these emotion components in chapters 4, 5, 6, and 7.

The choices made also warrant a brief discussion on why there is less emphasis of possible bottom-up effects on emotion from for instance motor expressions in the emotion model used and studies based thereon. Note that we do not wish to downplay the importance of potential bottom-up effects of the emotion components on emotional responses (Carney et al., 2015). But there are some problems with the bottom-up thesis of emotion in relation to motor expressions specifically that suggest that caution is warranted (Pfaf, 2014; Price & Harmon-Jones, 2015; Roseman, 2004; Ranehill et al., 2015; Stanton, 2011). We will discuss the three main ones:

1. There is substantial evidence that emotions caused by events via appraisal processes exert a much stronger effect on the emerging emotional response than manipulating say, emotion caused by a motor expression (Roseman, 2004; Siemer et al., 2007). For instance, when people are asked to smile throughout a sad movie clip, they will still feel sad afterward (Tourangeau, & Ellsworth, 1979). This suggests that bottom-up effects of motor expressions are limited.

2. A recent meta-review on reaction time studies of approach and avoidance movements indicated that motor expressions are likely to only influence behaviour when they happen at the same time as an emotion-relevant event (Pfaf et al., 2014). For instance, approach and avoidance arm movements only influenced behaviour when people were asked to appraise the emotion on a face, rather than non-emotional aspects such as a face's spatial properties (Rotteveel et al., 2004). This suggests explicitly that an event and its appraisal are required for motor expressions to influence emotion.
3. Recent replication issues of the Carney et al. (2010) study suggest that caution is warranted with claims about strong bottom-up effects of motor expressions on emotion (Price & Harmon-Jones, 2015). The replication showed no effects of power poses on cortisol and testosterone (neuroendocrine component), nor any effects on three behavioural tasks that were similar to the tasks used in Cuddy et al. studies (Ranehill et al., 2015). This despite a much larger sample, and treatment of previous issues in the measurement approach used in the Carney et al. study (Stanton, 2011). We follow Price & Harmon-Jones (2015) in their assessment that caution is warranted in basing any theory on the Carney et al. studies at this point.

In light of this evidence, we feel it is most constructive to our own studies to focus on the importance of events and appraisals in causing emotion, and the subsequent role of motor expressions in regulating emotions, rather than focusing more strongly on any bottom-up effects. This, we feel, justifies the use of the componential model in the studies presented in this thesis.

With the componential perspective on emotion in mind, we will now review empirical findings on the relationships between emotion and creativity.

2.2.1 Emotion and the creative process

To arrive at a creative outcome people cycle back and forth through a range of information processing steps, which have been characterised as: 1) problem definition, 2) information gathering, 3) concept selection, 4) conceptual combination, 5) idea generation, 6) idea evaluation, 7) implementation planning, and 8) solution monitoring (Mumford et al., 2012). For instance, in the conceptual combination step in the creative process one might combine concepts related to jogging and music, from which the idea is generated to make running shoes with a built in music player, which is evaluated as original but not very effective, which prompts people to therefore cycle a few steps back in the creative process to generate more ideas. This process is typically referred to as *the creative process.* See Figure 2.

Creativity in part depends on the way the steps in the creative process are executed. Creativity can be enabled when each activity in the creative process is executed in a way that enables effective information processing in the next (Mumford et al., 2012). However, creativity can be augmented when these activities are executed in a way that favours the emergence of original and effective outcomes (Mumford et al., 2012). For instance, increased flexibility in information processing during idea generation makes it easier to generate many and diverse ideas, which helps provide enough material to develop an original outcome from. Subsequent idea evaluation benefits from a focusing on details and systematically going through the generated ideas to ensure that they are indeed original and can be developed into an effective outcome (Isaksen et al., 2011; Mumford et al., 2012).

The adaptive changes in the way people think and act that are associated with different emotions, and the influence of these changes on the way the creative process is executed, can therefore influence creativity (Baas et al., 2008; Davis, 2009). As such, emotions can diminish creativity when the adaptive response that constitutes an emotion works against the factors that determine an effective execution of an activity in the creative process. Conversely, emotions can augment creativity when they benefit the execution of activities in the creative process in a way that favours the emergence of original and effective outcomes (Baas et al., 2008; Davis, 2009).

2.2.1.1 Positive emotion augments problem definition, information gathering, and idea generation

Emotions can be thought of in terms of the positive (e.g. happiness, pride) experience they are often associated with (Scherer, 2009). Positive emotions emerge from the appraisal that events are conducive to an individual's goals (Scherer, 2009). Positive emotions influence the flexibility with which information is made available to different processes that are involved in the creative process (Baas et al., 2008). For instance, an increase in flexibility increases the chance that more remote concepts are combined to generate ideas, which in turn increases the likelihood that a generated idea is an original one. The association between positive emotion and flexibility can be explained through the neuro-endocrine component, as positive emotions associate with dopaminergic activity in the prefrontal and anterior cingulate cortex, and the striatum (Akhbari Chermahini & Hommel, 2012b; Ashby et al., 1999), which plays a role in regulating the flexibility with which information is relayed to other brain areas (Dreisbach & Goschke, 2004; Dreisbach et al., 2005). In addition, self-reported positive feelings also associate with enhanced idea generation (Baas et al., 2008). Although the link between positive emotion and creativity is most apparent during idea generation (see Baas et al., 2008 for a meta-review), recent findings have also shown that the flexibility that is associated with positive emotions can benefit insight and creativity during the problem definition (Chen et al., 2014) and information gathering (Gasper & Zawadzki, 2012) steps in the creative process.

2.2.1.2 Negative emotion may or may not have an influence on emotion

Emotions can also be thought of in terms of the negative (e.g. anger, fear, sadness) experience they associate with (Scherer, 2009). Negative emotions happen when an event is appraised in a way that implies that it obstructs progress toward an individual's goals. Different negative emotions influence creativity in different ways. However, from the literature it is not clear whether the commonality between different negative emotions (i.e. they are caused by goal-obstruction) enhances or diminishes an aspect of the creative process in particular (see Baas et al., 2008 for a review). The adaptive response that is typically associated with negativity is an increased focus on the event that causes the negative emotion (Baas et al., 2008). Although negativity have been linked to detail oriented and step-by-step information processing, which can possibly enhance idea evaluation and diminish idea generation (Baas et al., 2008), recent findings have also shown that this only holds for (negative) emotions caused by the appraisal that the outcome of an event is uncertain, such as anxiety (section 2.2.1.3). Furthermore, some negative emotions associate with motivational factors that are beneficial to creative thinking such as an increase in arousal in the case of for instance fear, or approach motivation in the case of for instance anger (section 2.2.2). Therefore it is not clear from the literature whether the adaptive changes that associate with the negative aspects of an emotion have an influence on other steps in the creative process (Baas et al., 2008).

2.2.1.3 Emotions that associate with uncertainty augment idea evaluation

Emotions can also be thought of in terms of whether they associate with certainty or uncertainty. For instance, happiness and anger associate with certainty, whereas anxiety and some cases of sadness and fear associate with uncertainty (Baas et al., 2011; Scherer, 2009). Emotions that associate with uncertainty occur when it is difficult to predict the outcome of an emotion-relevant event. Certainty enables the use of heuristics (Tiedens & Linton, 2001), whereas uncertainty associates with a structured, step-by-step, and detail-oriented approach to information processing in order to increase the likelihood that more certainty can be obtained about the situation (Baas et al., 2012; Tiedens & Linton, 2001). The latter can inhibit performance during idea generation because it drives a focus on details, which limits generating many and diverse ideas. However, it can augment *idea evaluation*, the deliberative and reflective kind, because systematic information processing increases the likelihood that flaws in the details of a generated idea are discovered (cf. Sowden & Dawson, 2011).

2.2.1.4 Mixed emotions, an open question.

Mixed emotions happen when people experience both positive and negative emotions simultaneously (Larsen & McGraw, 2011). For instance, this can occur when events are appraised as both conducive and obstructive to different goals a person has which may lead to the emergence of simultaneous positive and negative feelings (cf. Larsen & McGraw, 2011). Others have suggested that mixed emotions can also be caused when different emotion components carry contrary emotional meaning (Huang & Galinsky, 2011). For instance, when frowning angrily while being in a situation that is evaluated as pleasant (Huang & Galinsky, 2011). Mixed emotions can potentially augment performance on idea generation because they drive the feeling that the situation an individual is in is an unusual one (Huang & Galinsky, 2011). Empirical findings suggest that mixed emotions can either drive an adaptive response that might resolve the situation quickly, for example by accepting an unusual solution to the situation (Huang & Galinsky, 2011), or may drive attention to seeking out what is unusual in the environment (Fong, 2006). For instance, a recent study showed that people categorize a broader range of exemplars as belonging to a particular category when emotion components are incompatible, for instance, by smiling in a sad situation, than when they experience a singular emotion (Huang & Galinsky, 2011). It follows that this might augment idea generation. This has however, not been tested explicitly yet.

2.2.2 Emotion, motivation, and creativity

Motivation can enable creativity through the arousal, direction, and persistence that form part of motivational processes (Amabile & Collins, 1999; Roskes et al., 2013; Sternberg & Lubart, 1996). Motivation is important because creativity can be demanding to the individual. This is in part because it requires the execution of complex and parallel cognitive processes (Mumford et al., 2012), and in part because it carries risks about whether the necessary investment of resources in a creative task, outweighs its potential reward (Dewett, 2004; Unsworth & Clegg, 2010). Therefore, a certain degree of motivation is often seen as a necessary condition for creativity to occur (Baas et al., 2008; Sternberg & Lubart, 1996).

Motivation can help ensure that people invest sufficient resources into a creative task, to persist throughout the creative process, despite the demands the creative process poses. For instance, *arousal*, the activation of the sympathetic nervous system, associates with attention to and maintenance of the goals relevant to a creative process (de Dreu et al., 2012); the *direction* of motivation, for instance, the tendency to avoid or approach, determines whether people invest their motivational resources in the creative process or elsewhere (Roskes et al., 2013); and *persistence* can enable people to compensate when the way they adapt to a situation is initially not conducive to performance (Baas et al., 2008).

Emotions influence the arousal, direction, and persistence of people's behaviour in various ways (Elliott et al., 2013; Russell, 2003; Scherer, 2009). Emotion can therefore enable creativity via its link with the processes that associate with motivation.

2.2.2.1 Emotional arousal enables creativity

Emotions differ in the degree of arousal people tend to experience during those emotions (Russell, 2003). Different appraisals drive an increase or decrease in arousal. For example, happiness, anger, and fear associate with higher levels of arousal than sadness or relaxation (cf. Scherer, 2005). At the neuro-endocrine level emotional arousal associates with noradrenergic activity, and associates with the regulation of working memory capacity (Chamberlain et al., 2006; de Dreu et al., 2008), i.e. the ability to keep information available for activities that involve processing multiple elements (Baddeley, 2003). Increased working memory capacity can help increase attention to and maintenance of the goals relevant to a creative process (de Dreu et al., 2012). Therefore, emotions that associate with higher levels of arousal associate with creativity more those that associate with lower levels of arousal (de Dreu et al., 2008; Filipowicz, 2006; To et al., 2012).

2.2.2.2 Approach action tendencies support motivation (and positive emotion)

Emotions can also be thought of in terms of their action tendency components, which help determine the direction of an individual's behaviour (Frijda, 2007; Scherer, 2009). Approach action tendencies, the activation of goals and tendencies that drive behaviour toward the pursuit of positive outcomes (Schacter et al., 2011, p. 300), typically emerge as part of an emotion (e.g. joy, anger) when people appraise an event as goal-conducive and they believe that they have the resource to produce a positive outcome (Milgram & Tenne, 2000). Assuming that a creative task can facilitate a positive outcome, approach tendencies can direct motivation toward the creative task, which enables creativity (Baas et al., 2011). This can be explained at the neuro-endocrine level by an association between approach tendencies and dopaminergic activity that associates approach tendencies with working memory capacity, persistence, and flexibility (Salamone et al., 2012). In addition, approach rather than avoidance arm gestures have been shown to influence creativity during idea generation and insight problem solving (Friedman & Förster, 2002). Moreover, approach action tendencies also associate with an increase in flexibility (Friedman & Förster, 2005), which can augment creativity during idea generation, information gathering, and problem finding (as described in section 2.2.1.1). This can be explained by the observation that the motivation to pursue positive outcomes is likely to increase positive emotion (cf. Baas et al., 2008; Baas et al., 2011). Therefore, emotions that involve approach action tendencies can enable creativity.

2.2.2.3 Avoidance action tendencies can enable persistence

Avoidance action tendencies, the activation of goals and tendencies that drive behaviour away from, that is to avoid, negative outcomes (Schacter et al., 2011, p. 300), typically emerge as part of an emotion when events are appraised as threatening, and people believe that they do not have the resources to cope with the situation (Milgram & Tenne, 2000). Avoidance tendencies associate with a relatively narrow and detail oriented manner of information processing (Friedman & Förster, 2005). Therefore, avoidance tendencies are typically not associated with creativity (cf. Baas et al, 2008; Sowden & Dawson, 2011). However, when a creative task is believed to facilitate avoiding something negative, people tend to direct more motivational resources to that creative task and persist longer at that task (Roskes et al., 2012; 2013). This in turn help enable creativity in that particular circumstance. Therefore, emotions that involve avoidance action tendencies can enable creativity when creativity can help facilitate the avoidance of negative outcomes.

2.2.3 Summary

We have reviewed empirical research from psychology on the relationship between emotion and creativity. This review provides knowledge about the aspects of emotion that an interactive system designed to influence emotion, can attempt to target when it is designed with the goal to augment creativity (see Table 1 for an overview).

The review indicates that the link between emotion and creativity can be targeted by the influence of emotion on the way people think and act during a creative process. Positive emotion can augment creativity during problem finding, information gathering, and idea generation. Negative emotion has no influence, or diminishes creativity during idea generation, but it is unclear whether negative emotions influence other steps in the creative process. Emotions that associate with uncertainty diminish creativity during idea generation, but augment idea evaluation. Finally, mixed emotions might be a way to target idea generation (section 2.2.1).

The review also indicates that the link between emotion and creativity can be targeted by the influence of emotion on motivation. Emotional arousal increases attention to and maintenance of the goals relevant to a creative process, enabling creativity. Approach action tendencies direct motivational resources to the creative process, and support positive emotion. Finally, when creativity facilitates avoiding something negative, emotions that associate with avoidance action tendencies can increase the persistence necessary to enable creativity (section 2.2.2).

The literature review presents an overview of the current state of empirical research from psychology and the relationship between emotion and creativity, and different aspects thereof. These different aspects can be used as a target for an interactive system that aims to influence the emotion creativity link. That is, a designer of such a system can pick a (combination of) aspects of emotion to influence creativity or a particular step therein. The overview provided in Table 1 is added to provide a starting point.

In the research presented in this thesis we will focus on developing interactive systems that attempt to influence the relationship between positive and negative emotions, and creativity (sections 2.2.1.1, 2.2.1.2).

That is, positive and negative emotions are the targets for the interactive systems developed.

This is motivated by the following observations:

1. The differential effects of *positive and negative emotions* on creativity *during idea generation* have the most solid base of empirical research to support their relationship with creativity (Baas et al., 2008; Davis, 2009). A focus on positive and negative emotions within the context of idea generation is therefore a good way to investigate our developed approaches to interactive systems can be used to target the emotion-creativity link.
2. A focus on positive and negative emotion will also enable us to compare our own research to an extensive body of previous work. This can be used to support our focus on the mechanisms underlying the impact of the designed interactive systems on the emotion-creativity link. The latter, we feel will strengthen our contribution.
3. Positive and negative emotions can be self-reported by asking people about the feelings experienced during a creative task. Using self-report is a limitation imposed by the available resources for the studies in this thesis. From the literature it is unclear to what extent other (aspects of) emotion can be self-reported on reliably. This we will address in detail in the discussion section (section 3.3.3).

It follows from these arguments that the contribution of the reviewed literature about the relationship between emotion and creativity supports the use of positive and negative emotions as a target for the designed approaches, and provides an overview for opportunities to develop other types of approaches that target aspects of emotion other than the positivity and negativity of an emotional response.

Emotion components					Mediating factor	Creativity	Section
Appraisal	*Action tendency*	*Somatic*	*Motor*	*Feeling*			
Goal-conducive		Dopaminergic activity		Positive	Flexibility of information processing	Enhances problem def.	2.2.1.1
						Enhances info. gathering	
						Enhances insight	
						Enhances idea generation	
Goal-obstructive				Negative	Problem focus	Unknown	2.2.1.2
					(Possibly) Step-by-step analytical processing	(Possibly) Enhances idea evaluation	
					(Possibly) Persistence	(Possibly) enables creative process	
Uncertainty	Resolve uncertainty				Step-by-step analytical processing	Enhances idea evaluation	2.2.1.3
Mixed	Resolve unusualness		(possibly) incompatibility	Positive/ negative	Focus on unusualness, breadth of thinking	Idea generation	2.2.1.4
		Noradrenergic activity		Arousal	Working memory capacity	Enables creative process	2.2.2.1
	Approach	Dopaminergic activity	Approach arm poses		Flexibility	Enhances idea generation	2.2.2.2
					Mobilization resources toward creative process	Enables creative process	
	Avoidance		Avoidance arm poses		Mobilization resources away from process	Disables creative process	2.2.2.3
					Persistence (dependent on situation)	Enables creative process (dependent on situation)	

Table 1 Overview of the reviewed literature on the relationship between emotion and creativity taken from the perspective of the emotion components.

2.3 Interactive systems that influence emotion and augment creativity

To enable an interactive system to influence the relationship between emotion and creativity, to augment creativity, the system needs to be able to influence emotion in a manner that suits creativity. In this section we will review previous research on interactive systems that are designed to help influence emotion, interactive systems that augment creativity, and interactive systems that are designed to influence emotion in order to augment creativity. The goal of this review is to position the research that is presented in this thesis within the spectrum of these technological developments, to provide arguments for its novelty, and identify possible constraints that can inform the development of our own approach to such interactive systems.

2.3.1 Interactive systems that influence emotion

Interactive systems can be designed to make use of the role of emotion in human functioning. For example, such interactive systems can be designed to: 1) Make use of the role of emotion in communication, to endow interactive systems with communication channels that are natural and intuitive to people; 2) adapt the way the system interacts to the changes that associate with different emotions (in the way people think and act), to support people by helping them choose the tasks that suit the emotions they are having; and 3) influence emotion to help determine the way people think and act, in order to help users adapt to different situations (Picard, 1997; Scherer et al., 2010). The research presented in this thesis is about the latter.

We distinguish between four common ways in which interactive systems influence emotion to help determine the way people think and act.

2.3.1.1 Integration of techniques from psychology in interactive systems

Interactive systems often attempt to appropriate commonly used techniques to induce emotion that are developed in the psychological sciences for experimental research purposes, such as exposing users to pictures, music, movie scenes, or situations that have some bearing on emotion (cf. Lench et al., 2011). For instance, an adaptive music player was developed that can monitor peoples skin conductance responses to different songs, and, assuming a correlation between skin conductance and arousal, is then able to select and play the songs that calm people down or get them to be more excited (van der Zwaag et al., 2012). Other examples include interactive environments that convey images (Lewis et al., 2011), music (Morris et al., 2013), movie scenes (Giannoullis & Verbeek, 2009), smells (Giannoullis & Verbeek, 2009), and situations (Chittaro & Zangrando, 2010) that associate with emotion.

2.3.1.2 Physiological techniques and biofeedback

Some interactive systems utilize the role of human physiology in emotion, to influence emotion. Such techniques can use the biofeedback paradigm, i.e. presenting signals from the body back to the user with the goal that the user learns to influence these signals, and with these signals, influence their own emotions. For instance, a system designed to display a user's EEG, with the instruction for users to change their behaviour such that their EEG patterns fit a predetermined pattern that associates with increased empathy, increases empathy in virtual environments (Cavazza et al., 2014). Other approaches use the communicative value of physiological signals to influence emotion. For instance, a ring that can be worn, and is designed to convey the heartbeat of another person, influences feelings of intimacy (Janssen et al., 2010).

2.3.1.3 Mirrors and mirroring

The manipulation of facial expressions of people in a manner that influences emotion can also be used to develop interactive systems that influence emotion. Some manipulation techniques focus on humoristic manipulations of the user's own face (Melder et al., 2007; Shahid et al., 2013). For instance, in analogy to the distorting mirror seen at carnivals, digital manipulations of one's own face can be made, which can be used to cause positive emotions (Shahid et al., 2013). An alternative approach is to manipulate the face of other's during interpersonal communication. Here, the tendency of people to mirror (mimic) each other's facial expressions is used (Niedenthal, 2007). For instance, subtle manipulations of facial expressions using a video-conferencing tool, to make the person a user is talking to look more positive or negative, influences emotion in the user accordingly (Yoshida et al., 2013).

2.3.1.4 Mimicking social interaction

The majority of interactive systems that are designed to influence emotion attempt to mimic the ways in which people influence each other's emotions during interpersonal communication (Broekens et al., 2009; Fong et al., 2003). Such interactive systems make use of the facial expressions, postures, gestures, and vocal expressions people use to influence a user's emotions (de Rooij et al., 2013). This approach aims to develop computer generated social interactions. This may include mirroring as discussed in the section above, but generally involves a broad set of emotional behaviours that need to be mimicked, which can include mirroring. For instance, mimicking social interactions can mean that some expressions can be designed to generate mirroring behaviours in the user (e.g. confirming positivity and approval in a confederate) (Hatfield et al., 2014). This can be done by endowing an anthropomorphic robot with the ability to mimic facial expressions. Some expressions however may not cause mirroring, but lead to counter-mimicry as a way of coping or regulating another's emotional response (e.g. in the case of anger from a peer or a superior). Therefore, emotion recognition systems and computational models of emotion are necessary to determine in situ the expression that is appropriate, and when it should be expressed (Broekens et al., 2009). This way, mimicking social interactions can be an effective way to influence a user's emotions and influence any associated adaptive behaviours. For instance, virtual avatars endowed with these capabilities can make people feel encouraged when these avatars express empathy at appropriate moments (McQuiggan & Lester, 2007).

2.3.2 Interactive systems that augment creativity

In order to help people get more out of their own creative capabilities interactive systems can be designed to 1) support and augment creativity when people engage in a creative task, 2) aid the development and training of creativity, and 3) enable people to have new experiences that may inspire them to do creative work (Nakakoji, 2005). The research presented in this thesis focuses on the first.

We distinguish between three common ways in which interactive systems support and augment creativity when an individual engages in creative work (after Bonnardel & Zenasni, 2010; Lubart, 2005).

2.3.2.1 Unburdening the creative process

Interactive systems can be designed to enable a user to effectively execute the creative process (Shneiderman, 2007). This can be done by designing environments that minimize the burden on a user's cognitive resources by minimizing the resources needed to deal with any functionality of an interactive system that is not conducive to creativity (Bonnardel & Zenasni, 2010). For instance, Cycling '74 Max/MSP is a visual programming environment for media creation which allows access to advanced signal processing algorithms, and lets users explore the results of their programming in real-time (cf. Shneiderman, 2007). This supports the creative process because it allows users to construct algorithms and explore the results without the need to wait for the software to compile. This makes it easier for a user to focus on the creative process. This in turn makes generating and evaluating ideas easier when compared to traditional programming languages, which require the user to compile the code before its result can be seen.

2.3.2.2 Supporting the use of creativity techniques

Interactive systems can also focus explicitly on augmenting activities in the creative process by explicitly supporting the use of creativity techniques such as brainstorming or analogical reasoning (Hewett, 2005; Sisarica et al., 2013; Zachos et al., 2013). This can be done by using techniques that provide users with heuristics that help them execute the creative process in a manner that augments creativity. For instance, a mobile application that is developed for dementia carers supports idea generation by letting people find solutions to a problem from one domain by considering it in another, in order to support analogical reasoning (Zachos et al., 2013). The application allows a carer to input a situation that the carer encounters that requires a creative solution. Based on this input the application prompts the user with possible solutions that have been developed for similar situations that have occurred in a different domain. This can inspire the user to translate these ideas to their own situation and thereby helps the user to get more out of their own creative capabilities.

2.3.2.3 Collaborating with intelligent machines

Interactive systems can also be designed to collaborate with the user during the creative process (Kantosalo et al., 2014). Such systems make use of artificial intelligence techniques to carry out parts of the creative process, whose output takes over and informs parts of the user's own creative process. For instance, an interactive system that has been developed to design drugs uses simulated evolution to automate idea generation (Lameijer et al., 2006). The system automatically combines and mutates molecular structures. The results are presented to the user who evaluates them and decides what molecular structures should be developed further. This way, the interactive system takes over aspects of the idea generation activity, and presents the results to the user for idea evaluation. This enables the computer to take over aspects of the creative process, and collaborate with the user to arrive at a creative outcome.

2.3.3 Interactive systems that influence emotion to augment creativity

Interactive systems can be designed to influence emotion, and via emotion, augment creativity. Such an approach to interactive systems is different from the reviewed interactive systems that augment creativity (section 2.3.2), because it attempts to prepare the way the user thinks and acts, in a way that supports the execution of a creative process, and by supporting the motivation necessary to do a creative task (section 2.2). That is, it taps into the ability of people to adapt to different situations, and supports that process in a manner that is conducive to creativity. This in itself is a relatively novel approach to interactive systems that aim to augment creativity.

This is the approach we follow in the studies that are detailed in this thesis.

2.3.3.1 Current attempts

Until now there have been relatively few attempts at designing such systems. There is some work on the integration of emotion induction methods from psychology in digital platforms (section 2.3.1.1).

Priming techniques using pictures that have some bearing on emotion have been used on a crowdsourcing platform as a way to induce emotion during an idea generation task (Lewis et al., 2011). In this study, pictures were presented and placed next to a verbal and a visual idea generation task on a computer screen. These pictures contained either positive (e.g. a happy baby), neutral (e.g. a file cabinet), or negative (e.g. a natural disaster) content. The study did not discriminate between other aspects of emotion (e.g. action tendencies or arousal) and all participants were motivated extrinsically by paying them a small amount of money upon completing each task. In the verbal idea generation task participants were asked to generate many alternative uses for a common object (e.g. a brick). In this task, showing both positive and negative pictures led people to generate more original uses for a common object when compared to being presented with neutral pictures. Contrary to common findings in the literature no significant differences were found between the positive and negative conditions. In the visual idea generation tasks participants were asked to draw as many sketches as they could on the basis of a circle. Results of this task showed that presenting positive images rather than neutral or negative images led people to draw significantly more original sketches. Overall, this study confirms that the relationship between positive and negative emotion can be targeted by means of an interactive technology, which further justifies our own focus on positive and negative emotions during idea generation. However, this study also suggests that there may be differences in the effectiveness with which the way emotion is targeted (here with pictures that contain emotional content). The latter justifies our own studies which aim to investigate novel ways in which the link between emotion and creativity can be targeted.

Similarly, another study investigated the influence of listening to musical excerpts just before doing the remote associates task (RAT) on a crowdsourcing platform (Morris et al., 2013). The RAT asks people to find a word that is in common with three other given words (e.g. the correct solution for *fish, mine, rush* is *gold*). This task is used as a proxy to measure general creative ability. Here, participants were also extrinsically motivated by paying them a small sum of money upon completion. The experimental manipulations were 30-second musical excerpts of positive (Bach's

Brandenburg concerto) and negative music (Prokofiev's Alexander Nevsky: Russian under the Mongolian yoke). As a neutral condition no music was used but people were asked to write down the date. Results for this study were mixed. Initially, positive music enhanced performance on the RAT when compared to listening to negative music or writing down the date. However, a pre-screening task indicated that while there was a trend that indicated that positive feelings prior led to better creative task performance than negative feelings, the 25% of most negatively feeling participants outperformed other participants. There, the authors discriminated between positive and negative emotions as well as arousal, but did not find effects of self-reported arousal on creativity as measured during the RAT. The latter confirms that the relationship between positive and negative emotion can be investigated, also within the context of interactive systems. However, this study also suggests that the link between positive and negative emotion, the way in which these are elicited, and creativity is complicated.

Finally, there is a study that used the tendency of people to mirror each other's facial expressions (section 2.3.1.3) as a means to target the link between positive and negative emotions during a collaborative idea generation task (Nakazato et al., 2014). Here two participants were asked to collaborate to generate alternative uses for a common object (e.g. a brick). This collaboration was mediated by a video conferencing tool that automatically manipulated the user's facial expressions to be more positive or more negative than they were in reality (Yoshida et al., 2013). This study also did not discriminate between aspects other than the positivity or negativity of an emotion. The study results indicated that collaborating with a person whose face was manipulated to look more positive, led people to generate more original ideas than when people collaborate with a person whose face was manipulated to look more negative. These findings are in line with research on the link between positive and negative emotions and creativity during idea generation. Moreover, these findings again confirm that the emotion-creativity link can be targeted using an interactive system.

The few existing research projects that have been developed until now indicate that:

1. The development of interactive systems that aim to target the emotion-creativity link is a relatively novel and unexplored field of research. That is, there are only three studies by others that address this relationship explicitly. This justifies our studies from an interactive systems perspective.
2. Positive and negative emotion can be targeted using an interactive system in a manner that is conducive to creativity during amongst others idea generation. This justifies further our own focus on the effects of positive and negative emotions on creativity during idea generation tasks.
3. Other aspects of emotion than its positivity or negativity are not explicitly focused on or were found ineffective in the research that is currently available. Although this is an opportunity for novel research, we focus on the mechanisms underlying new ways of targeting the emotion-creativity link.
4. Interestingly, the studies also indicate that the means with which an interactive system influences the emotion-creativity link matters with regard to the effectiveness of such interactive systems, and possibly with regard to the manner in which positive and negative emotions affect creativity. The latter justifies our own studies into

novel ways in which interactive systems can target the emotion-creativity link.

The latter will be discussed in further detail in the next section.

2.3.3.2 Limitations and a critique of current attempts

Since the field is new, little is yet known about how interactive systems should be designed to effectively influence emotion in a way that suits creativity. The studies discussed in the above section indicated that the way in which an interactive system targets the link between emotion and creativity matters. However, given the little amount of research on such interactive systems, we may turn to empirical research from psychology on the influence of emotion induction techniques on creativity for some further insight into this.

We believe that the main issue that such technologies need to overcome is that the adaptive influence of emotion on the way people think and act, depends on the nature of the events that cause emotion, and the situation in which these emotions are caused (Russell, 2003; Wilson-Mendenhall et al., 2013). For instance, fear in response to a threat, e.g. seeing a dangerous animal, consists of a somewhat different adaptive response than fear that is caused in a social situation, e.g. in anticipation of public speaking (Wilson-Mendenhall et al., 2013). Thus, one would expect that an emotion that is caused by an event that has nothing to do with a creative task, may influence creativity differently.

Although there are no studies in the context of creativity-emotion research that address this explicitly, we can turn to research on cognitive control (see Goschke & Bolte, 2014 for a review). There, empirical studies have shown that emotion that is induced in a manner that is generally task irrelevant can lead to different effects than emotions that are caused in a manner that is relevant to the task. For instance, recent studies on working memory performance (which we have linked earlier to task performance during the creative process, section 2.2) showed that positive emotions that are induced via pictures displayed prior to a task-switching task can impair working memory performance, whereas performance contingent rewards enhanced working memory performance (Goschke & Bolte, 2014).

If we compare this to research on the emotion-creativity link (section 2.2) we could argue that there is a possibility that using task-irrelevant methods to influence emotion are likely to lack the needed arousal (de Dreu et al., 2011) or possible approach action tendencies (Roskes et al., 2013) to enable creativity. That is, pictures used to target emotion may muster insufficient motivational resources. The question then becomes whether this is because these studies did not control for differences in arousal and approach motivation for instance (section 2.2.2). So one conclusion could be that an interactive system that aims to target the link between positive and negative emotions and creativity should also explicitly target arousal and approach motivation, or at least make sure that possible different levels of arousal and different motivational directions are elicited by task irrelevant emotion.

If we compare this to research on interactive systems that are designed to influence the emotion-creativity link (section 2.3.3.1) we can also argue for an alternative solution. Rather than using task-irrelevant means to cause very specific emotions prior or during a creative task, we argue that the way in which an interactive system should cause emotion, should be due to the task itself. That is, the manner in which emotions are caused should task-relevant.

We believe that there are several lines of evidence that support the latter.

First, the research on cognitive control suggests that emotions that are caused by task-relevant means influence working memory capacity positively, which is a major condition for creativity to occur (Goschke & Bolte, 2014). Rather than targeting emotions that are arousing or approach motivated, the same effect on working memory can potentially be achieved by making sure that any emotions that are caused are believed by the user to come from the task itself. That is, a system that ensures that emotions are caused (or believed to be caused) by the creative task itself should result in sufficient allocation of motivational resources to do the creative task in a manner that can enable creativity.

Second, there are differences in the effectiveness with which different means can influence emotion that also relate to differences in task-irrelevance and task-relevance (see Lench et al., 2011 for a meta-review). For instance, when comparing different methods used to influence emotion, the use of pictures that have some bearing on emotion, in a way that is not related to a task, e.g. showing a picture of a happy baby (Lewis et al., 2011), does not lead to much adaptive change, if any, when compared to influencing positive emotions that happen in response to the task, e.g. by rewarding performance on the task (Chiew & Braver, 2014). This further justifies our own focus on interactive systems that target the emotion-creativity link by task-relevant means.

Third, literature about the effectiveness of emotion induction techniques prior to, and irrelevant to a creative task specifically further support these observations. When an emotion is induced prior to a creative task and in a way that does not relate to the task, there may be an influence on creativity but it is short lived (Kaufmann & Vosburg, 2002; Nouri & Maiden, 2013). For instance, inducing happiness rather than sadness prior to an idea generation task only benefits idea generation in the first minute of the task, after which creative task performance is similar for both ways of inducing emotion (Kaufmann & Vosburg, 2002). Similarly, emotions generated prior to a creative activity only influence creativity when people believe that these prior emotions apply to a creative task. For instance, the negative influence of sadness on idea generation task performance disappears when people are told that they are free to come up with any idea they want (Gasper, 2003). The latter leads us to question the utility of such an approach for interactive systems and suggests further that any means with which emotion is targeted during a creative task should be relevant somehow to that particular creative task.

These observations can further be supported by interpreting the potential use of interactive systems that influence emotion within the conditions posed by creative tasks (see section 2.3.1). For instance, in the previously described experiment on using facial deformation during a video conference brain-storm session (section 2.3.3.1), the technique that is used is meaningful because the user is tricked into thinking that another person, i.e. the person with whom they engage during a brain-storm session, is positive about the brain-storm session. In this specific case this is a meaningful source of emotion because people influence each other's emotions through social interaction, and social interaction is an inherent part of brain-storming with multiple people (cf. Paulus & Nijstad, 2003). In other domains we see that social interaction can be mimicked to have similar effects, e.g.

human-like robot tutors that mimic the student-tutor relationship (Woolf, 2009) (section 2.3.1.4). However, there are many situations that require creativity where there is no such analogy that can be exploited, because many creative activities are done alone. Thus, the development of an interesting system is not trivial if we assume that these need to be task-relevant (i.e. meaningful in a creative context) to be effective. However, our previous discussions indicate that this is a necessary condition to develop interactive systems that are effective in their ability to influence the emotion-creativity link.

On the basis of the arguments presented in this section we believe that research into the development of new ways in which interactive systems can be designed to effectively influence the relationship between positive and negative emotions and creativity during idea generation is justified. This does however raise the question of how we should design an interactive system that is relevant or meaningful to a creative task, such that it can effectively influence emotion in a manner that is conducive to creativity.

This question is the subject of the research done in this thesis (chapters 4, 5, 6, and 7).

2.3.4 Summary

This brief review on existing attempts to develop interactive systems that utilize the relationship between creativity and emotion shows that it is possible to do this, and suggests that we can view this as a relatively new category of systems designed to augment creativity.

However, empirical research from psychology suggests that using existing interactive systems to influence emotion is limited when used within the context of creativity. We have argued that the technique that is used to influence emotion must be meaningful within the context of the creative process for it to effectively influence the relationship between emotion and creativity (section 2.3.3.2).

If we compare these empirical findings from psychology (section 2.3.3.2) with the review on interactive systems that are designed to influence emotion (section 2.3.1), we see that these developed techniques offer few opportunities. For instance, mirroring and mimicking social interaction are typically only meaningful in creative contexts where there is a precedent to have social interactions, whereas much creativity happens alone. The use of techniques translated from psychology, as well as techniques focusing on physiology and biofeedback may be effective for a short time when they are used prior to a creative task, but again, these are unlikely to effectively utilize the relationship between emotion and creativity during a creative activity, because they are not a meaningful part of the creative task itself.

Therefore, new techniques are required for the design of interactive systems that aim to utilize the relationship between creativity and emotion. These techniques will be the focus of our studies.

2.4 Summary of the literature review

In this chapter we have presented a review on empirical findings from psychology on the relationship between *emotion and creativity* (section 2.2). This review provides the aspects of emotion that can enable and augment creativity through their influence on the *creative process* (section 2.2.1), and on the *motivational* factors that are necessary to execute the creative process (section 2.2.2). This informs the conception of interactive systems by providing the aspects of emotion that the system can influence.

We have also reviewed research on interactive systems (section 2.3). This review provides a brief overview of *interactive systems that influence emotion* (section 2.3.1), *interactive systems that augment creativity* (section 2.3.2), and a review about the existing approaches to *interactive systems that influence emotion to augment creativity* (section 2.3.3). This is done with the goal to position our research, and to uncover potential issues with using existing interactive systems designed to influence emotion, to augment creativity. The findings in this review imply that a new approach is required.

We believe that to remedy the discussed issues that associate with creating interactive systems that use the emotion-creativity link, there can broadly be two types of approaches.

First, an interactive system can be designed to regulate the emotions that are caused by the creative task. In study 1 (chapter 4) and study 2 (chapter 5) we develop such an approach to interactive systems, which is able to effectively hack into the function of motor expressions in emotion regulation (*RQ1*). Also see Figure 3.

Second, an interactive system can be designed to cause the emotions that are typically caused by a creative task. In study 3 (chapter 6) and study 4 (chapter 7) we develop such an approach to interactive systems, which is able to effectively hack into the cognitive appraisal processes that help cause emotion, and at least to some extent can help to determine the intensity of these caused emotions (*RQ2*). Also see Figure 3.

These interactive systems are designed to hack into the link between positive and negative emotions, and creativity (sections 2.2.1.1, 2.2.1.2). That is, influencing positive and negative emotions during a creative task is the focus of the capabilities of the two approaches to interactive systems that are developed. Within this context, we focus in particular on the abilities of the interactive systems to influence the link between positive and negative emotions, and creativity during idea generation (section 2.2.1.1, 2.2.1.2).

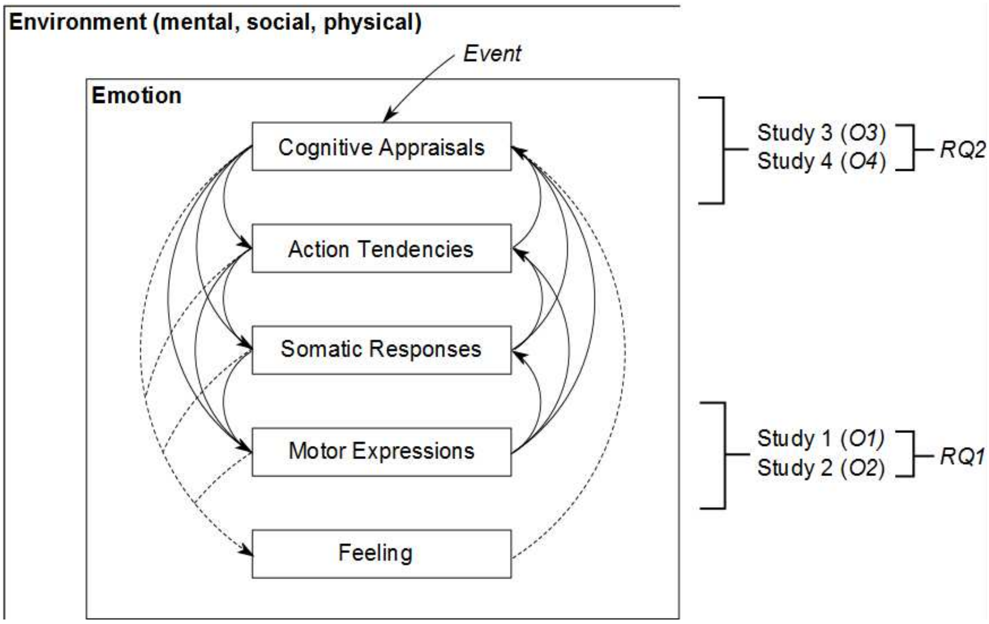

Figure 3 Schematic of the emotion components we focus on in the studies described in this thesis. Studies 1 (O1) and 2 (O2) focus on motor expressions, which inform the first type of approach to interactive systems we develop (RQ1), whereas studies 3 (O3) and 4 (O4) focus on the cognitive appraisal processes, which inform the second type of approach to interactive systems that aim to hack into the emotion-creativity link (RQ2).

3. Methods

3.1 Introduction

In this chapter, we discuss the general methodological framework, the materials and measurement instruments that are used in our studies, and our particular use of quantitative methods. The goal of this chapter is to discuss the rationale behind the methodological choices made. To accommodate the reader, we also provide an overview of the methods used in the individual studies.

3.2 General methodological framework

The research presented in this thesis describes the development of two novel approaches to interactive systems that influence the relationship between emotion and creativity. In particular, the studies focus on explicating the mechanisms underlying the developed approaches. We have argued that this requires knowledge about those aspects of emotion that augment or diminish creativity (section 2.2), and a way for an interactive system to influence emotion in a manner that suits creativity (section 2.3.3.2). From an interactive systems perspective, such research is in an early stage (section 2.3.3.1). However, research from the psychological sciences is more advanced (sections 2.2.1, 2.2.2). Therefore, we base most of our methodology on the latter.

3.2.1 Conception

The current state of related research from the psychological sciences suggests that a *confirmatory* rather than an exploratory research method can be used (Johnson & Christensen, 2008). That is, test a priori hypotheses.

This is because there is sufficient available empirical research from the psychological sciences based on which we can conceive our interactive systems (sections 5.3, 6.3, 7.3). To this end we attempt to bring together empirical findings about the emotion-creativity link (section 2.2), with existing empirical findings about the things that influence emotion during a creative task (sections 4.2, 5.2,6.2, 7.2). Based on this, we can develop testable hypotheses about the influence of our developed approaches to interactive systems on the emotion-creativity link, which lend themselves to empirical investigation (sections 4.3, 5.4.4, 6.4.4, 7.4.1).

3.2.2 Making

To empirically confirm the effectiveness of the conceived approaches to interactive systems, we also develop a 'proof of concept' interactive system for each of these approaches (sections 5.4, 6.4). This is a common strategy in interactive systems research, as it helps to validate an approach within an interactive systems context (cf. Olson & Kellog, 2014). The process of making also helps to shape our intuitions about the theoretical basis of the developed approaches, which further supports the process of research as a whole (cf. Lamers et al., 2013). Note that these proof of concept interactive systems are specifically designed to test the hypotheses, which limits their external validity with regard to practical application, but enables us to demonstrate better the mechanisms underlying our approaches (cf. Hornbæk, 2013). We assume that demonstration with a proof of concept further supports the intended contribution of the research presented in this thesis.

3.2.3 Experimental evaluation

The confirmatory approach adopted in this research suggests the use of randomized experimental study designs (Johnson & Christensen, 2008). Therefore, we adopted the standard approach to randomized experiments as described in (Shadish, et al., 2002). The studies described in this thesis will be conducted under controlled conditions, as is consistent with our aim to demonstrate the workings of our developed approaches (cf. Olson & Kellog, 2014). Following the positivist tradition, we assume that if the data obtained in the studies uphold the hypotheses, the conjectured approach to developing interactive systems supports the intended contribution of the research presented in this thesis. The particulars of the experimental designs that were used are described in the method section of each study chapter (sections 4.5, 5.5, 6.5, 7.5).

A fundamental question regarding the results of experimental studies is how valid they are, i.e. the extent to which the results generalize (Shadish et al., 2002). To discuss the validity of the results of our studies we adopt the four *threats to validity* framework as described by (Shadish et al., 2002):

1. *Conclusion validity* - the degree to which conclusions that are reached about the relationships in the data obtained in the study are reasonable.
2. *Internal validity* - the degree to which we can place confidence in the cause and effect relationship in the study.
3. *Construct validity* - the degree to which the instruments and tests used, measure what is claimed to be measured.
4. *External validity* - the degree to which the results of the study can be generalized to other people and to other situations.

We will use the threats to validity framework as a checklist during the design, and interpretation of the results, of our studies. Possible threats to validity will be discussed where appropriate.

3.3 Materials and measurements

To enable the experimental study of the influence of the developed approaches to interactive systems on the emotion-creativity link, we need to make some decisions about the materials and measurement instruments we use. First, we need *creative tasks* to gather data based on which creativity can be assessed. Second, we need a measurement instrument to *assess creativity* in order to quantify the gathered data, which is used to evaluate whether the developed interactive systems influence creativity. Third, we need a measurement instrument to *assess emotion,* which can be used to tie the influence of an interactive system on creativity, to the emotion-creativity link. The rationale for the materials and measurements used will be addressed in these sections. Because these determine in part the validity of the experiments, we also discuss possible threats to validity that we either need to accept, or that we can address in our study designs.

3.3.1 Creative tasks

To gather data based on which creativity can be assessed, we require a *creative task.* We previously argued that individual creativity depends on the execution of the creative process and on motivation (section 2.2). The processes underlying these, however, differ with the context in which creativity occurs (e.g. Mumford et al., 2010; Dewett, 2004). This suggests that creativity is best studied in situ (Amabile, 1983). Emotions, however, differ in the way that they influence the execution of different steps in the creative process (section 2.2.1). This complicates experimental evaluation of creativity as a whole. For similar reasons, researchers often resort to psychometric tasks (cf. Baas et al., 2008), which can emulate individual steps in the creative process, and provide test situations to study motivational factors underlying creativity, in isolation (Cropley, 2000). We follow the same approach.

Of these psychometric tasks, the Alternative Uses Task (AUT) is used to emulate the idea generation step in the creative process (Zheng et al., 2011). The AUT typically requires people to list as many, diverse, and original uses for a common object (e.g. a paperclip) as they can (Lee, 2004). This mimics the function of idea generation in creativity, i.e. generating sufficiently diverse material from which original ideas can be developed (Cropley, 2006). Note however, this test does not allow for testing people's ability to generate effective ideas (Runco & Jaeger, 2012), and therefore has limited construct validity as a task for evaluating creativity as a whole (Zheng et al., 2011). However, it does suit our studies, because the link between positive and negative emotions, which we aim to study, is thought to support originality, rather than effectiveness (section 2.2.1.1).

The construct validity of the AUT is relatively strong when used as a measure of creativity during idea generation (Runco & Acar, 2012). This does, however, depend on how it is administered (Zheng et al., 2011). The following issues need to be addressed or accepted in our study designs:

1. The results of an AUT are susceptible to its instructions (Silvia et al., 2008). To emulate idea generation more accurately, instructions must prime the goals people have that are typical for idea generation during the creative process (cf. Cropley, 2006). Measurement error can be

reduced by framing the instructions such that the generation of original ideas is emphasized (Lee, 2004).

2. The AUT is also susceptible to training effects (Baer, 1996). Measurement error, here, can be reduced by minimizing the chance that people do the AUT multiple times.
3. The AUT concerns trivial objects (e.g. bricks, paperclips) which might not motivate people in the manner that a real-world creative process would (cf. Zheng et al., 2011). Given the relationship between motivation and creativity, it may yield results that are different from the ones it purports to measure. This we need to accept when using the AUT.

The way these possible threats to validity are addressed in our studies is described in the method sections of the study chapters (sections 4.5.2.1, 5.5.2.1, 6.5.2.1, 7.5.2.1).

3.3.2 Assessment of creativity

A measurement instrument to *assess creativity* is necessary to quantify the data gathered with the adopted creative tasks. Typically, the results from a creative process can be judged based on the originality and effectiveness of its outcomes (Amabile, 1983). When a creative task is done in situ, domain experts can be asked to reach a consensus about what ideas are original and effective (Kaufman et al., 2009). However, in psychometric tasks, such as the AUT, problems tend to be more abstract and trivial (Zheng et al., 2011). In such cases, people tend to agree less on what's original and unoriginal (cf. Dunbar & Forster, 2009; Kaufman et al., 2009), which indicates that a consensual approach is not a reliable measure for such creative tasks. Therefore, researchers often resort to *objective scoring* methods, which aim to quantify the data obtained from a creative task by using basic statistical operations (Guilford, 1967). In our studies we use the objective scoring method as follows.

The objective scoring method used in our studies assesses creativity as fluency (amount of ideas), flexibility (amount of concepts used), and originality (statistical infrequency of ideas) (Guilford, 1967). It is already clear that, in line with the use of psychometric tasks such as the AUT, objective scoring does not enable assessment of effectiveness (Zheng et al., 2011). It does, however, offer a way to assess potential underlying mechanisms that are argued to enable the generation of original ideas, i.e. fluency and flexibility (Isaksen et al., 2011; Mumford et al., 2012). This suits our studies, because the link between positive and negative emotions is thought to support originality (section 2.2.1.1).

The construct validity of the objective scoring method is typically high (Plucker et al., 2014), and can be generalized at least to some extent to creative ability as a whole (Runco & Acar, 2012). There may, however, be several potential sources of measurement error that either need to be accepted, or need to be addressed in our study design:

1. Fluency is confounded with originality (Silvia et al., 2011). That is, generating more ideas increases the likelihood that these ideas are statistically infrequent. Measurement error can be reduced by recalculating the originality scores in a way that corrects for fluency (e.g. the percentage of original ideas) (Plucker et al., 2011).
2. Originality as assessed with the objective scoring method is ambiguous (Silvia et al., 2011). That is, both original and bizarre ideas are statistically infrequent. Measurement error cannot be reduced without introducing some form of subjective judgment (e.g. Benedek et al., 2013).

3. Originality as assessed with the objective scoring method correlates negatively with sample size (Silvia et al., 2011). That is, the likelihood that a generated idea is statistically infrequent decreases when the amount of ideas used to assess this increase. This we need to accept when using the objective scoring method.

The way these possible threats to validity are addressed in our studies is described in the method sections of the study chapters (sections 4.5.2.2, 5.5.2.2, 6.5.2.2, 7.5.2.2).

3.3.3 Assessment of emotion

Furthermore, a measurement instrument is needed to *assess emotion,* which can be used to tie the influence of an interactive system on creativity, to the emotion-creativity link. We previously explained that emotions include changes in emotion components (section 2.2). It has been argued that the only way to assess emotion is to assess all of these changes in the emotion components (Scherer, 2005a). That is, assess cognitive appraisals, action tendencies, somatic and neuro-endocrine responses, motor expressions, and feelings. See (Mauss & Robinson, 2009) for a review. It is, however, unclear to what extent measures of the emotion components can be combined to assess emotion (Hollenstein & Lanteigne, 2014). Therefore, researchers often resort to the assessment of feelings alone (Feldman Barret, 2004). That is, assessing only the aspects of the emotion components that can be subjectively experienced (Scherer, 2009). We follow the same approach.

Feelings can only be assessed by asking people about them (Gray & Watson, 2007; Larsen & Prizmic-Larsen, 2006). This requires people to translate the aspects of the emotion components they can experience, into a medium that suits our quantitative methods. Not all changes in the emotion components can be subjectively experienced (Scherer, 2005b); instead, people experience the gist of an emotion. It is, however, commonly accepted that feelings allow people to distinguish between positive and negative emotions, indicate their intensity, and levels of arousal (Gray & Watson, 2007; Reisenzein, 1994). Self-report can therefore be used in our studies, because we exclusively focus on the relationship between positive and negative emotions, their intensity, and creativity (section 2.2.1.1).

It has been argued that, because self-reported feelings are subjective reports, construct validity is always high, unless participants are untruthful (Gray & Watson, 2007). Nevertheless, there may be several potential sources of measurement error that either need to be accepted, or need to be addressed in our study design:

1. The response format used biases what is reported (Scherer, 2005b). Measurement error can be reduced by using scales, rather than categories, since scales better mimic the aspects of an emotion people can experience (Gray & Watson, 2007).
2. Feelings are only accessible during an emotion (Scherer, 2009), but self-report at that moment would interfere with the creative task. Measurement error can be reduced by limiting the time between an emotion and the moment of self-report (Gray & Watson, 2007).
3. Feelings can be recalled from memory, after the time at which an emotion happened (Robinson & Clore, 2002). Measurement error can be reduced by supporting recall, by explicitly referring to the situation and particular emotional feelings that are of interest to the study (Gray & Watson, 2007).

The way these possible threats to validity are addressed in our studies is described in the method sections of the study chapters (sections 4.5.2.3, 5.5.2.3, 6.5.2.3, 7.5.2.3).

3.3.4 Manipulation checks

To support the internal validity of the experimental designs, we carry out manipulation checks, check for possible alternative causes, and confounding variables that could provide an alternative explanation of the effects of the interactive systems on the emotion-creativity link (Shadish, et al., 2002). The checks that are carried out are particular to each study, and are described in the method sections of the study chapters (section 4.5.2.4, 5.5.2.4, 6.5.2.4, 7.5.2.5).

3.4 Quantitative methods

The use of randomized experimental study designs suggests the use of quantitative methods to support the validity of the conclusions that will be drawn from the collected data (Shadish et al., 2002). That is, we assume that, because we can make very specific predictions about the effects of our interactive systems on the emotion-creativity link, the results should only be accepted as significant if it is very unlikely that the effects found can be due to chance. Quantitative methods can aid here by supporting the conclusion validity of any claims made (Field, 2013).

In each study we make use of the descriptive and inferential statistical methods that are appropriate to the used experimental designs. We follow the recommendations of quantitative methods for experimental studies as described in (Field, 2013). Because the relationship under investigation is a dependent one (i.e. the effect of the interactive systems on creativity via its effects on emotion), we supplement these methods by the use of (Pearson) correlations as suggested by (Hayes, 2013). This results in the following use of quantitative methods:

1. *Descriptive statistics* – to describe the central tendency and variability of the obtained data.
2. *Correlations* - to test whether there is an association between emotion and creativity across the experimental conditions.
3. *Inferential statistics* - to test whether there is an effect of the way the interactive system is used on emotion, and on creativity, separately.

This particular cascade of quantitative methods is used to explicate the mechanisms underlying the effects of the interactive systems on the emotion-creativity link, and as such, can help provide evidence for the way our approaches to interactive systems are conceived (sections 5.6, 7.6). That is, we assume that if the inferential statistics show that there is an effect of the experimental conditions, i.e. the way the proof-of-concept interactive systems are configured, on creativity (section 3.3.2) and on emotion (section 3.3.3) separately, and there is also a correlation between the measures creativity and emotion variables, this is treated as evidence that the designed interactive system can effectively influence the emotion-creativity link. The particular quantitative methods that are used are discussed throughout the results sections of each study chapter (sections 4.6, 5.6, 6.6, 7.6).

3.5 Summary

In this chapter we have discussed the general methodological framework, the materials and measurement instruments, and approach to quantitative methods used in our studies. We suggest that combining conception (i.e.

synthesising a theoretical basis), based on empirical findings from psychology (section 3.2.1), with making proof of concept interactive systems (section 3.2.2), and testing the use of these systems using randomized experimental studies, is the appropriate general methodological framework for our studies (section 3.2.3).

Given the restrictions and opportunities posed by the adopted methodological framework, the focus of our studies on the relationship between positive and negative emotion, and the focus of our studies on the idea generation step in the creative process, we selected three types of materials and measurement instruments. We adopted the Alternative Uses Task as a way to gather data about creativity during idea generation (section 3.3.1), assessed creativity using the objective scoring method (section 3.3.2), and asked people to self-report their feelings as a way to assess positive and negative emotions (section 3.3.3). Because we experimented with the way these materials and measurements were used, their details will be discussed further in each of the method sections of the study chapters (sections 4.5, 5.5, 6.5, 7.5).

Since we need to test whether the effects of our developed interactive systems influence emotion in a manner that augments or diminishes creativity, we will supplement the standard approach to using quantitative methods with the experimental designs used, with analyses that specifically facilitate testing such dependent relationships (section 3.4). Because different types of quantitative analyses suit the different experimental designs that we have used throughout our studies, we discuss their details further, where appropriate, in the results sections of the study chapters (sections 4.6, 5.6, 6.6, 7.6).

Finally, to further accommodate the reader, we now provide an overview of the methods used in the individual studies (section 3.6).

3.6 Overview of the methods used in the individual studies

As will be discussed in more detail in the study chapters, we have used different experimental designs to meet the needs of the different hypotheses developed to test our approaches to interactive systems. Within this context, we have also used different ways of implementing the measurement instruments, to address threats to construct validity of the measures used, and we have made use of different quantitative analyses to meet the demands of the used experimental designs. Here, we present an overview of the methods used in these individual studies (Table 2).

	Study 1	Study 2	Study 3	Study 4
Experimental design	- Between-subjects	- Between-subjects	- Within-subjects	- Between-subjects
Quantitative methods	- Mean, standard deviation - Pearson correlation - T-tests, ANCOVA - Sobel-test	- Mean, standard deviation - Pearson correlation - ANOVA	- Mean, standard deviation - Pearson correlation - Linear mixed model analysis	- Mean, standard deviation - Pearson correlation - ANOVA
Creative tasks	- AUT (problem solving variation)	- AUT - Insight problem solving test	- AUT	- AUT
Assessment of creativity	- Fluency - Flexibility - Originality	- Fluency - Flexibility - Originality (%)	- Originality (%) automated	- Originality (%) automated
Assessment of emotion	- Very unpleasant-very pleasant	- Very negative-very positive	- No satisfaction–much satisfaction - No frustration-much frustration	- No satisfaction–much satisfaction - No frustration-much frustration

Table 2 Overview of the different methods used in the study designs. This includes the experimental designs, quantitative analyses, creative tasks, and ways in which creativity and emotion were assessed.

4. Study 1: Motor expressions as creativity support

A paper that details the study discussed in this chapter was presented at the 27th International British Computer Society Human Computer Interaction Conference, September 2013, London, United Kingdom. This paper is included in Appendix B. A paper that expands on the findings in this experiment was presented at the doctoral consortium of the 19th International Conference on Intelligent User Interfaces, February 2014, Haifa, Israel. This paper is included in Appendix C.

4.1 Introduction

In this chapter, we review empirical research from psychology about the function of motor expressions in emotion regulation. Based on this review, we conjecture two ways in which motor expressions can augment creativity: congruence of motor expressions with emotions that are known to augment creativity, such as positive (section 2.2.1.1), rather than negative emotions (section 2.2.1.2); and incompatibility of a motor expression with an emotion (cf. section 2.2.1.4). Here, incompatibility refers specifically to incongruence between a motor expression and other emotion-relevant features that is sustained over a lengthy period of time, such that aside from a suppressive effect on emotion, an adaptive response akin to an emotion in its own right emerges (Huang & Galinsky, 2011). Two ways of posing motor expressions, that either associate with positive emotion and approach action tendencies, or with negative emotion and avoidance action tendencies, and two problem situations, that are either positive or negative, were designed to experimentally evaluate these conjectures. The study provides preliminary evidence and thereby demonstrates that motor expressions that associate with positive emotion and approaching action tendencies, rather than negative emotions and avoiding action tendencies, can augment creativity; and that incompatibility rather than congruence between a motor expression and an emotion can also augment creativity during idea generation. Note that this study does not test the function of motor expressions within the context of interactive systems, rather, the study is aimed at exploring new ways in which motor expressions can influence the emotion-creativity link which aims to justify further exploration in an interactive systems context. Thus, the contribution of this study is a demonstration of two ways in which imposing motor expressions can help regulate emotion and augment creativity (*research objective O1*). This justifies using the function of motor expressions in emotion regulation within an interactive systems context, which, we believe, is a good first step towards answering *research question RQ1*.

4.2 Motor expressions and emotion

Motor expressions are the physical actions that form part of an emotion (Dael et al., 2012; Ellgring & Scherer, 2007a; 2007b). For instance, we smile when we see something nice, or we might push away the things we do not like. Motor expressions also regulate emotion (Critchley & Nagai, 2012; Price et al., 2012). That is, motor expressions enable people to exert some degree of control over their own emotional responses (Gross, 1998). This is because the emotion components do not only feed forward to help determine a motor expression, motor expressions also feed back into these emotion components to regulate emotion (Moors, 2013; Scherer, 2009).

That is, the feedback relationships that exist between motor expressions and the other emotion components enable expressions to influence the disposition towards having certain emotions, and to influence the intensity of those emotions (Critchley & Nagai, 2012; Price et al., 2012).

The function of motor expressions in emotion regulation can be described from three perspectives.

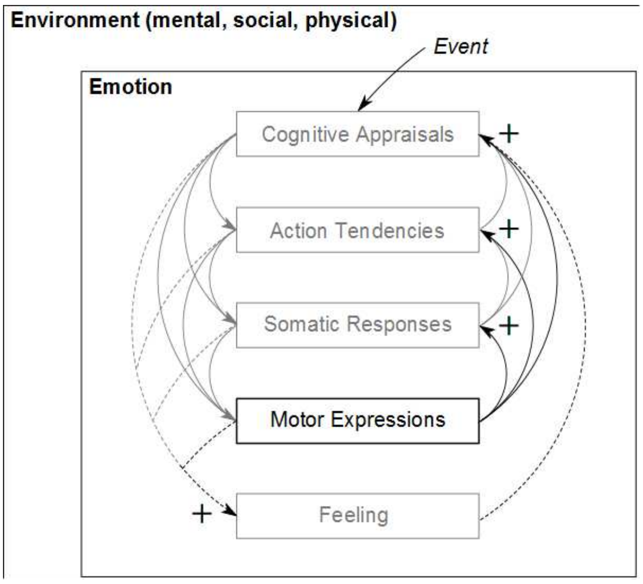

Figure 4 Schematic of the function of motor expression congruence in emotion regulation. Congruence of a motor expression with an emotion feeds back into the somatic responses, action tendencies, and cognitive appraisals, which increases disposition towards, and increases the intensity of, congruent emotions, via positive feedback (+). Some aspects of motor expressions might feed forward into shaping an individual's feelings, which then affects the way feelings can influence cognitive appraisal (dashed arrows).

Congruence between a motor expression and an emotion provides positive feedback to that emotion, which increases the disposition to have, and the intensity of, that emotion (Figure 4). For instance, smiling increases the pleasantness associated with pleasant pictures (Soussignan, 2002; Strack et al., 1988); arm flexion increases positive feelings when it suggests pulling something towards you that you desire, facilitating approach action tendencies (Centerbar et al., 2006; Cacioppo et al., 1993); smiling is shown to activate dopaminergic pathways in the brain (Wiswede et al., 2009); and mimicking emotion expressions increases the consciously experienced feelings of these same emotions (Flack, 2006; Flack et al., 1999). See (Critchley & Nagai, 2012; Price et al., 2012; Reimann et al., 2012) for overviews.

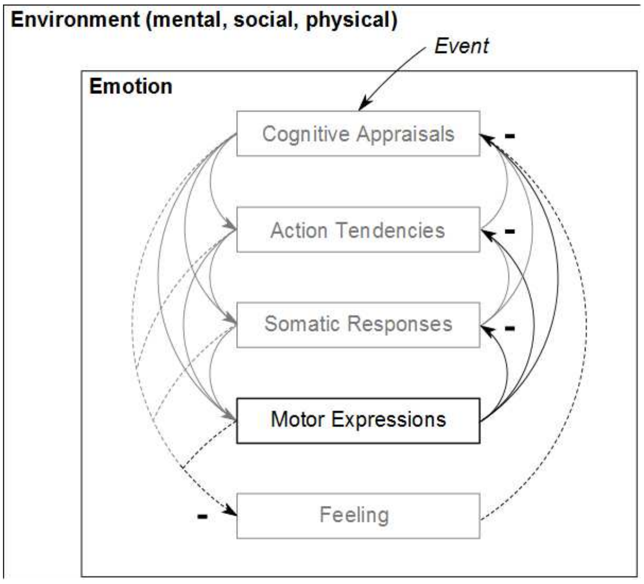

Figure 5 Schematic of the function of motor expression incongruence in emotion regulation. Incongruence between a motor expression and an emerging emotion can suppress the other emotion components by providing negative feedback (-), which decreases the disposition toward, and the intensity of, an emerging emotion. Some aspects of motor expressions might feed forward into suppressing individual's feelings, which then affects the way feelings can influence cognitive appraisal (dashed arrows). If incongruence is sustained over time, a sense of incompatibility can emerge, which drives an adaptive response akin to an in emotion in its own right.

Incongruence between a motor expression and an emotion provides negative feedback to that emotion, which decreases the disposition to have, and the intensity of, that emotion (Figure 5). Incongruence enables *suppression* of an emotion when a motor expression that would naturally occur as part of an emotion, is inhibited at the moment that emotion is caused (Centerbar et al., 2008; Gross, 1998). For instance, using BTA (commercially called Botox) to inhibit frowning reduces symptoms of mild depression (Davis et al., 2010; Finzi & Wasserman, 2006); inhibiting facial expressions that associate with a particular emotion, impair the ability of people to recognize that same emotion in others (Oberman et al., 2007); and, inhibiting motor expressions disrupts overall emotional processing (Centerbar et al., 2008; Gross, 1998; Neumann & Strack, 2000). The way we use the term incongruence in this thesis refers to a brief and timely mismatch between a motor expression and events that cause emotion which is assumed to suppress an emotional response and thereby negatively influence the intensity of an emotional response. Note that this is the focus of study 2 (chapter 5).

When *incongruence* persists over time, a sense of *incompatibility* can emerge, which not only suppresses emotion, but also causes a response akin to an emotion in its own right (Huang & Galinsky, 2011). This response is characterized by the appraisal and feeling that the situation is unusual, which drive a form of action tendency that moves people to quickly resolve this unusual situation (Huang & Galinsky, 2011). This particular response may be conducive to creative thinking, as we will discuss later (section 4.3). Incompatibility such as we defined here is then a form of incongruence that occurs when there is an incongruence that is sustained over time. This definition of incompatibility is what we focus on in this study (study 1).

Based on the discussed research, we conclude that the function of motor expressions in emotion regulation, suggests different ways in which motor expressions can help influence emotion. In this study we will explore motor expression congruence and incompatibility, within the context of augmenting creativity during idea generation.

4.3 Motor expressions and creativity

Emotions can augment creativity (section 2.2). However, little research exists about the relationship between the motor expressions and creativity. We conjecture that there are at least two ways in which motor expressions influence the emotion-creativity link.

First, motor expressions that are *congruent* with emotions that augment creativity (section 2.2), can increase the disposition to have, and the intensity of, these emotions. Positive emotions have been associated with an increase in the flexibility with which information is made available to processes that are involved in idea generation (section 2.2.1.1). Additionally, approach action tendencies are associated with an increased likelihood of having positive emotions (section 2.2.2.2). It follows that positive approaching motor expressions, rather than for instance negative avoiding motor expressions, increase positive emotion, and may therefore augment creativity. In line with this assumption, motor expressions that associate with approach rather than avoidance action tendencies have been shown to increase flexibility and creativity, during idea generation and insight problem solving (Friedman & Förster, 2002; Hao et al., 2014; Price & Harmon-Jones 2010). This leads to the first hypothesis.

H1: Positive approach, rather than negative avoidance expressions, augment creativity during idea generation.

Second, incompatibility of a motor expression with an emotion might also augment creativity. Empirical findings suggest that incongruence disturbs emotional processing, suppressing incongruent emotions (Centerbar et al., 2008; Gross, 1998). If persisted over sufficient time, incongruence reduces the bias people otherwise have toward congruent emotions, and emotion-relevant information. It has been argued that this essentially broadens a person's thought patterns (Huang & Galinsky, 2011), which might be conducive to creativity during idea generation (section 2.2.1). Furthermore, when incongruence leads to a sense of incompatibility, and this leads to feelings of unusualness, incompatibility may bias people to seek out the unusual in their environment (section 4.2). This suggests that incompatibility might augment creativity, because it might broaden the way people think and it may bias people to focus more easily on unusualness, both of which may be conducive to creativity during idea generation. In line with these conjectures, incompatibility between motor expressions and other emotion related events, such as emotional pictures and music, increases the unusualness of associations that people have in a categorization task (Huang & Galinsky, 2011). In addition, it has been argued that incompatibility might be one way to induce mixed emotions, which also has been linked to augmented creativity during idea generation (cf. section 2.2.1.4). This leads to the second hypothesis.

H2: Incompatibility between a motor expression and an emotion, rather than congruence, augments creativity during idea generation.

Testing these two possible ways in which motor expressions can influence the emotion-creativity link, may provide a justification for using the function of motor expressions in emotion regulation within an interactive systems context.

4.4 Task design

Before developing an interactive system that can make use of the function of motor expressions in emotion regulation, we first wanted to test the two hypotheses 'on paper.' This way, we can justify what approach to take when developing such an interactive system. To this end, we designed two poses that can be used to mimic motor expressions, and two problem situations that can be used with a creative task. We assume that these can be used to test the two hypothesized ways in which we believe motor expressions can influence creativity.

4.4.1 Motor expressions

We designed two poses based on characteristics of motor expressions: a *positive approaching pose* that consisted of smiling while sitting in a relaxed open posture, while posing arm flexion by holding the non-dominant arm under the table and slightly pushing upward with a balanced muscle force; and, a *negative avoiding pose*, that consisted of frowning while sitting in a slightly shrunken and tense posture, while performing arm extension by extending the arm and pushing away on the table top. These poses are designed based the motor expression characteristics that typically associate with positive emotion and approach action tendencies, and negative emotion and avoidance action tendencies (Ellgring & Scherer, 2007a; 2007b; Friedman & Förster, 2002; Scherer, 2009).

4.4.2 Problem situations

We also designed two different problem situations: a *positive situation* where participants were asked to imagine themselves in a situation where they encountered someone they found attractive, and their goal was to attract that person; or, a *negative situation*, where they were asked to imagine themselves in a situation where they encountered someone they found repulsive, and their goal was to get rid of that person.

4.5 Method

To investigate the hypotheses we undertook a small experimental study, using a 2 (motor expressions) × 2 (problem situations) between-subjects design. This experimental design enables us to test a direct link between the motor expressions, emotion, and creativity. It also enables testing the effects of incompatibility on creativity. That is, randomized assignment of both motor expressions and problem situations results can introduce incompatibility and no incompatibility. Incompatibility can therefore be tested as an interaction effect between the two independent variables. Assignment of the participants to the experimental conditions was randomized.

4.5.1 Participants

In total, 32 people (18 females, 14 males, M_{age}=32, SD_{age}=7.2) participated in the experiment. Two participants were excluded from the sample for failing to execute the experiment's instructions. This resulted in 30 usable cases. The participants were students and employees of City University London.

4.5.2 Materials and measurements

4.5.2.1 Creative task

To gather data based on which creativity could be assessed, the participants were instructed to use a variation of the AUT (section 3.3.1). The task used in this study differed from the way the AUT is typically used, in that its focus was on generating ideas that solved problem situations, rather than generating uses for common objects (cf. Guilford, 1967). The two problem situations used in the creative task are described in section 4.4.2. To help ensure that this task emulated the idea generation step in the creative process, we followed suggestions by (Lee et al., 2004), and emphasized originality alongside fluency and flexibility in the instructions. That is, participants were instructed to "*…come up with as many, diverse, and original solutions to the given problem situation as you can*". Participants were given 5 minutes to do this.

4.5.2.2 Assessment of creativity

To assess creativity based on the data gathered using the AUT we used the objective scoring method (section 3.3.2). We used the classical approach to objective scoring as proposed by (Guilford, 1967). That is, we counted the amount of ideas that a participant generated (*fluency*), the amount of semantic concepts used in the generated ideas (*flexibility*), and we assessed the statistical infrequency of the participants' ideas, given the ideas generated by all the participants (*originality*). Originality was assessed by counting the ideas of which there were no more than two instances in the whole sample (14% of the total amount of ideas in this study) (cf. Silvia et al., 2008). We did, however, not correct the originality score for fluency, which introduces measurement error (section 3.3.2). This weakens the validity of the way creativity is assessed, which we need to accept in this study.

4.5.2.3 Assessment of emotion

Participants self-reported positive and negative emotions, as the unpleasantness-pleasantness they felt during the creative task, using an 8-point Likert scale (1=very unpleasant, 8=very pleasant). Approaches to minimise possible threats to the validity of the way we assess emotion (section 3.3.3), were implemented as follows: scales rather than categories, with negative and positive emotion words at opposite ends, were used as a response format, which we felt best mimics the aspects of an emotion people can distinguish during self-report; to support people in accessing their feelings we made sure that a questionnaire that contained the self-report measure was administered right after the creative task; and to (further) support recall of feelings we phrased the instructions alongside this self-report measure in a manner that referred explicitly to the feelings (unpleasant-pleasant) and the situation (the creative task) that were of interest to the study, "*Did you experience the idea generation task as (un)pleasant?"* We assumed these would support the construct validity of this measurement instrument.

4.5.2.4 Manipulation checks

Several manipulation checks, and checks for possible alternative causes, were carried out to support the internal validity of the study design (section 3.3.4). Because we suspected that there were differences between the poses with regard to the effort it takes to keep them throughout the task, e.g. the negative avoidance expression requires a slight increase in muscle tension, whereas the positive approach expression requires taking a comfortable posture, people self-reported the degree to which keeping the pose was not effortful or effortful (1=little effort, 8=a lot of effort) and whether they were able to keep the pose throughout the creative task (1=unable, 8=able). Furthermore, to check whether the positive and negative problem situation indeed associated with positive and negative emotion people rated the unpleasantness-pleasantness of the problem situations (1=very unpleasant, 8=very pleasant) on a Likert scale (8 points).

4.5.3 Procedure

On arrival, participants were seated, handed an overview of the experiment's procedure, subsequently signed informed consent, and were asked to report some personal details (age, gender). After this, instructions were given for either the positive approaching, or the negative avoiding pose. These included that participants should try to keep their pose throughout the creative task. Furthermore, these instructions included a request to the participants that they should ensure that the pose was not uncomfortable, and that when they forgot to keep the pose, they should simply take it again when they realised this happened. The instructions for the poses were assigned randomly. After these instructions the participant took the instructed pose and attempted to keep the pose until after the idea generation task. Next, participants were handed instructions for the idea generation task. Participants were asked to imagine themselves in either the positive or negative problem situation. After the imagination procedure, participants were asked to come up with, and write down on paper, as many original ideas as they could in response to the given problem situation within 5 minutes. Time was kept by the researcher. Directly following the idea generation task the participants were asked to stop their instructed pose. After this a questionnaire was handed to the participants which they filled in right away. This questionnaire contained the measurement instruments used to assess emotion and carry out the manipulation checks. Note that the assessment of creativity was done at a later stage by the researcher. That is, after the data of all the participants was collected. Following completion of the questionnaire, participants were debriefed, and received a bar of chocolate for their efforts. A graphic representation of the procedure is presented in Figure 6.

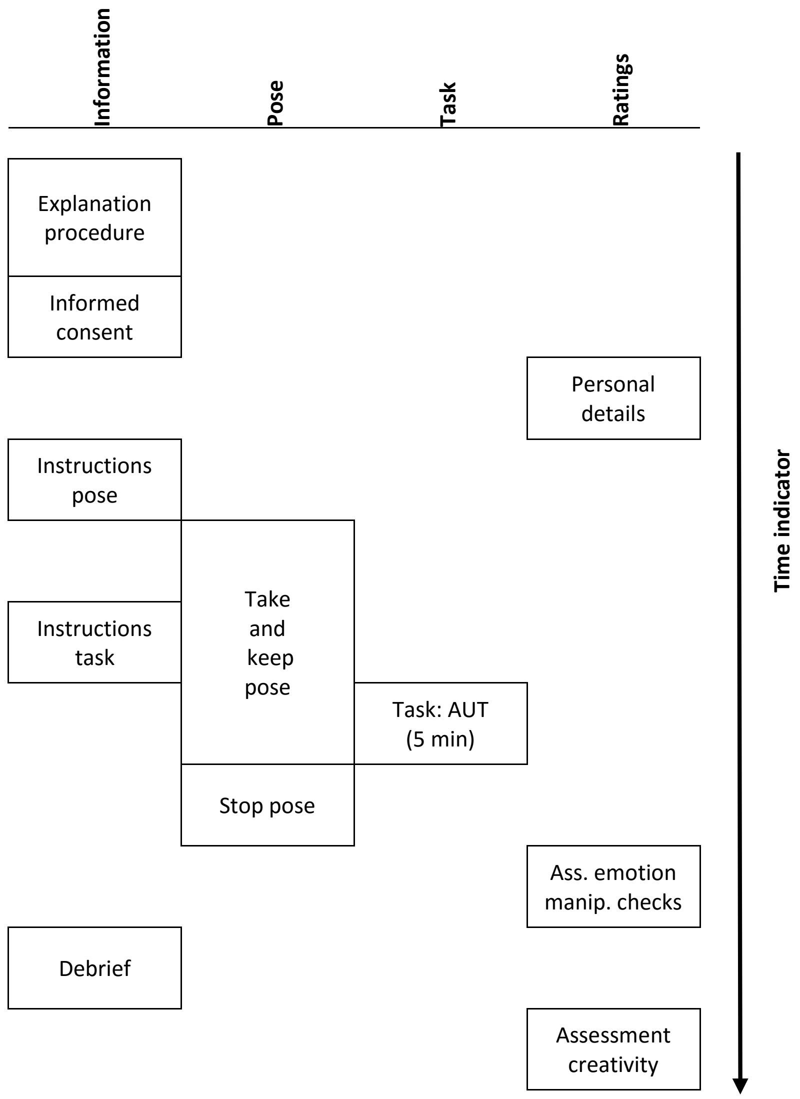

Figure 6 Graphic representation of the order and timing of information provided about the experiment, the moment the instructed pose was taken and thus when allegedly emotion should be influenced, the moment task was done, and ratings used in the procedure.

4.6 Results

We first carried out the manipulation checks, by submitting checks for effort and the ability to keep the pose individually as dependent variables (DV) to a t-test, with the posed motor expressions as the independent variable (IV). The results suggested that there was a significant difference between the motor expressions in the degree to which keeping the pose was not effortful or effortful, t(28)=-3.28, *p*=.003. The results showed that there was no significant differences between the motor expressions for the ability to keep the pose throughout the task, t(28)=.00, *p*=.947. To account for this additional source of variation, we included the effort ratings as a statistical covariant in further analysis.

We also did a manipulation check to test whether there was an effect of the problem situations on emotion, by submitting the unpleasantness-pleasantness of the problem situations as the DV to a t-test, with the problem situations as the IV. The results suggested that there was a significant difference between the problem situations for the pleasantness participants associated with these situations, t(28)=3.00, *p*=.006. This indicated that the imagined problem situations had the intended effect, which should enable testing for incompatibility.

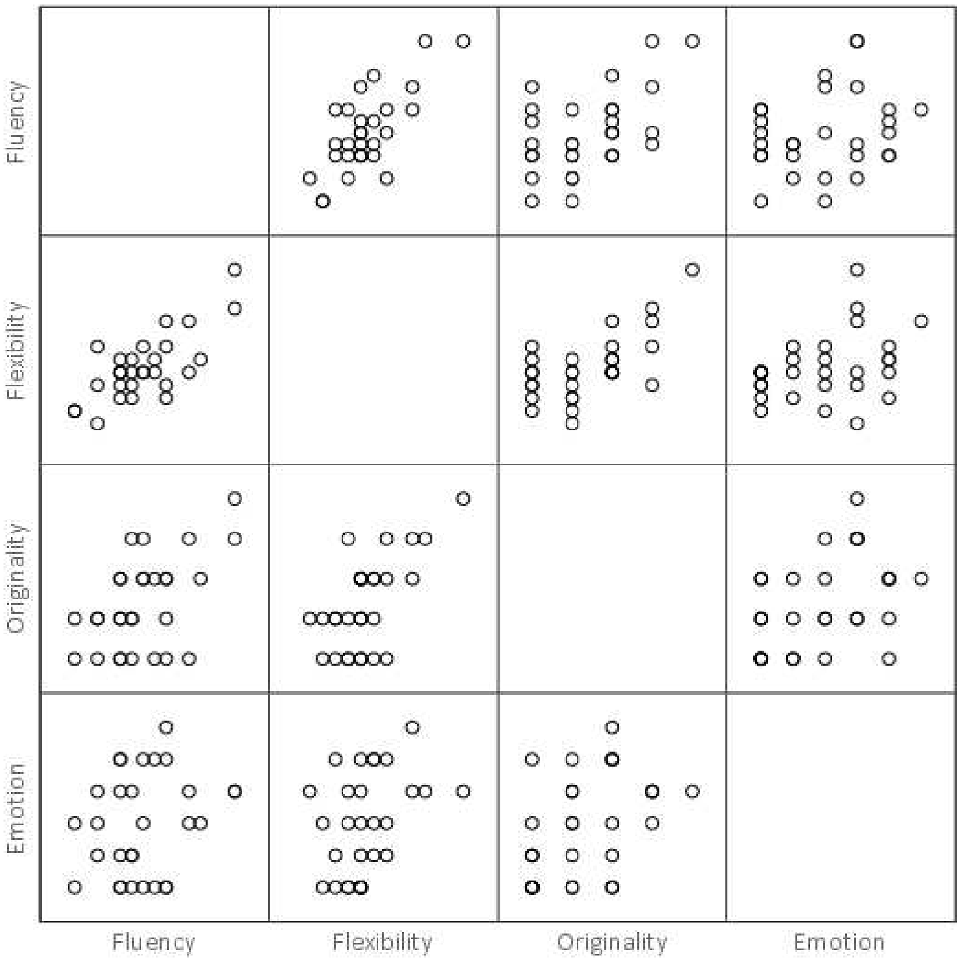

Figure 7 Scatterplot matrix of the dependent variables fluency, flexibility, originality, and emotion.

DV	Means	1.	2.	3.	4.
1. Fluency	10.10 (3.56)	-			
2. Flexibility	7.37 (2.52)	.714**	-		
3. Originality	1.38 (1.15)	.531**	.632**	-	
4. Emotion	4.90 (1.60)	.177	.360	.418*	-

*Table 3 Means, standard deviations (between parentheses), and Pearson correlation coefficients for the DVs fluency, flexibility, originality, and emotion. *p<.05, **p<.001.*

To test the two hypotheses we submitted fluency, flexibility, originality, and self-reported emotion individually as DVs to a 2 (motor expression) × 2 (problem situation) ANCOVA, with the degree to which the pose was effortful as the covariant. The descriptive statistics are presented in Table 3, a scatterplot matrix of the dependent variables is presented in Figure 7.

The results suggested that there was no effect of the problem situations on fluency, $F(1, 25)=.23$, $p=.635$, $\eta_p^2=.01$, flexibility, $F(1, 25)=.02$, $p=.882$, $\eta_p^2=.00$, and originality, $F(1, 24)=1.19$, $p=.286$, $\eta_p^2=.05$, and emotion, $F(1, 25)=.03$, $p=.856$, $\eta_p^2=.00$. This indicates that being exposed to a positive or negative problem situation did not yield observable differences in creativity, which was as expected. Interestingly, it also did not yield observable differences in emotion, which contrasts with the previous manipulation check we did on the problem situations.

The results further suggested that there was a significant difference between the motor expressions for emotion, $F(1, 25)=4.34$, $p=.048$, $\eta_p^2=.15$. These suggested that positive approach expressions (M=5.44, SD=1.63), lead to more positive emotions than negative avoidance expressions (M=4.29, SD=1.38). However, the results also suggested that there was no significant difference between the motor expressions for fluency, $F(1, 25)=1.23$, $p=.277$, $\eta_p^2=.05$, flexibility, $F(1, 25)=.32$, $p=.576$, $\eta_p^2=.01$, and originality, $F(1, 24)=.61$, $p=.807$, $\eta_p^2=.00$. There was however, a significant positive correlation between emotion and originality (Table 3). It may therefore be that the interaction between the problem situations and the motor expressions has led to results that interfere with the link between positive emotion and creativity due to the experimental setup. To circumvent this possible issue, we tested for mediation with a Sobel-test (Preacher & Hayes, 2004), with the motor expressions as the IV, emotion as the mediator, and originality as the DV. The results suggested that there was a significant indirect effect of the motor expressions on originality, Z=-1.77, *p*=.037. This indicates that positive approach, rather than negative avoidance expressions, augment creativity during idea generation, via the effect of the motor expressions on positive emotion. These results can at least to some extent be interpreted to support hypothesis H1.

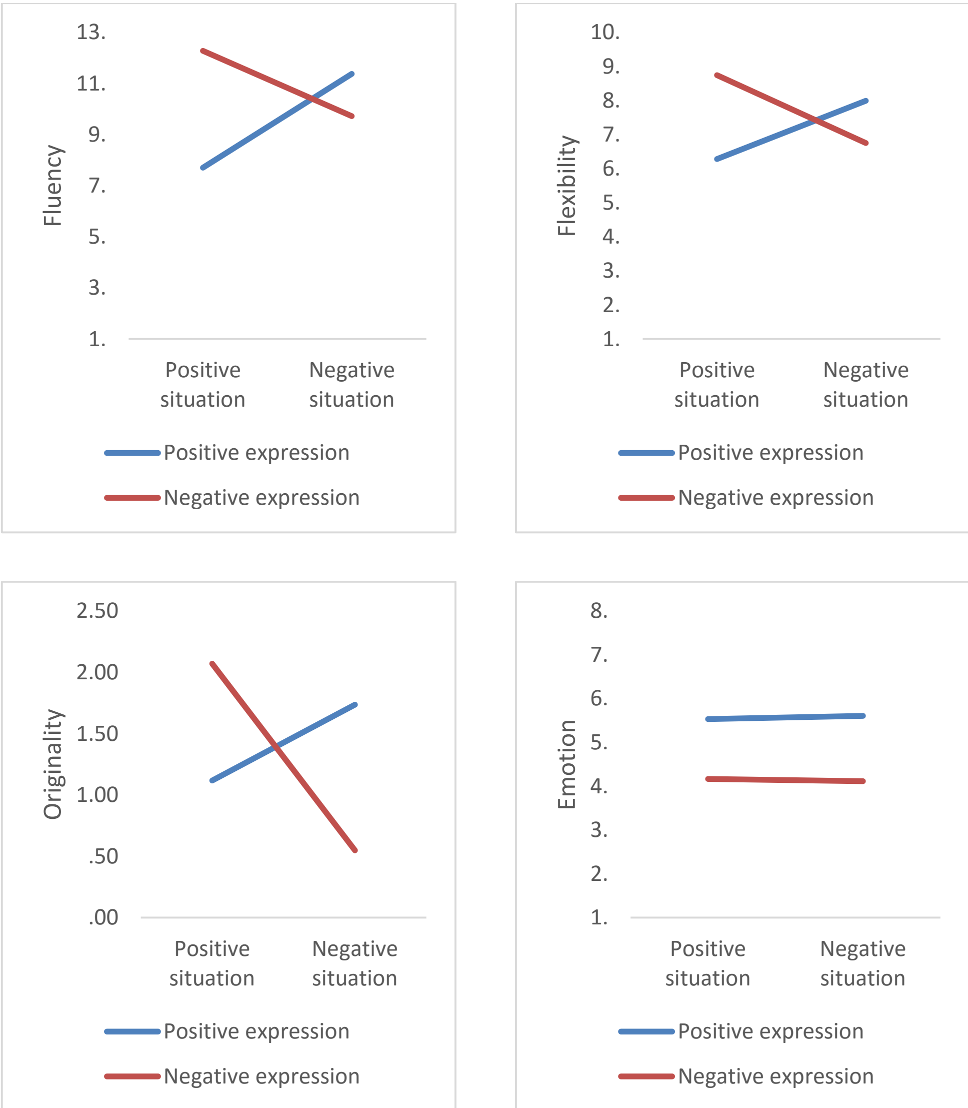

Figure 8 Estimated marginal means of the motor expression x problem situation interaction for the DVs fluency, flexibility, originality, and emotion.

The results also showed that there was a significant motor expression × problem situation interaction effect, for fluency, $F(1, 25)=7.60$, $p=.011$,

η_p^2=.23, and originality, $F(1, 24)$=7.08, p=.014, η_p^2=.23, but not for flexibility, $F(1, 25)$=4.01, p=.056, η_p^2=.14 (Figure 8). Positive approach or negative avoidance expressions increased fluency (Figure 8, Fluency), flexibility (Figure 8, Flexibility), and originality (Figure 8, Originality) when performed in the incompatible problem situation, rather than in the congruent problem situation. As expected, there was no significant interaction effect on emotion, $F(1, 25)$=.01, p=.916, η_p^2=.00. Positive approach, rather than negative avoidance arm gestures, led participants to self-report more positive emotion (Figure 8, Emotion). This effect on emotion, however, was not influenced by the problem situations. These findings suggest that incompatibility between a motor expression and an emotion, rather than congruence, augments creativity during idea generation. This finding appears to support hypothesis H2. However, because we did not find that the participants experienced differences in positive and negative emotion during the positive and negative problem situations it remains uncertain to what extent these findings can be attributed to any effects of incompatibility that is sustained over a longer period of time on the link between emotion and creativity.

4.7 Discussion

The findings in this study demonstrate two ways in which motor expressions can help regulate emotion and augment creativity (*research objective O1*).

The findings provide preliminary evidence for the hypothesis that positive approach, rather than negative avoidance expressions augment creativity during idea generation (H1). This indicates motor expressions can be used to regulate the emotions that augment creativity (section 2.2), and suggests one way in which motor expressions can be used to design interactive systems that make use of the emotion-creativity link. Our findings also provide preliminary evidence for the hypothesis that incompatibility between a motor expression and an emotion, rather than congruence also augments creativity during idea generation (H2). This suggests another way in which motor expressions can be used to design interactive systems that make use of the emotion-creativity link.

There were, however, also clear limitations that threaten the validity of claims made by us about the two hypotheses investigated.

First, the findings that indicate that motor expressions can be used to regulate the emotions that augment or diminish creativity, are limited by the fact that the results from the one-way ANOVA did not initially confirm this hypothesis because no effects were found on the assessed creativity measures (H1). However, positive results of the ANOVA for the effects of the posed motor expressions on emotion, and a positive correlation between the emotion and creativity variables indicated that there may be such a relationship in the data nonetheless. A mediation analysis confirmed this suspicion, and despite initial negative results, indicated that the posed motor expressions did indeed influence the relationship between emotion and creativity. We suspect that these initial negative results may have been an artefact of the used 2 x 2 design. This can possibly be explained by our other results, which suggested that the interaction effect between the used motor expressions and problem situations did affect the assessed creativity variables, and which may have obscured a direct effect of positive motor expressions on the link between positive emotion and creativity during idea generation, increasing chance of a type II error. Therefore, support for the hypothesis (H1) that positive approach, rather than negative avoidance expressions augment creativity during idea generation remains preliminary and needs to be interpreted with caution. However, we do believe that our findings are sufficient to justify investigating the use of motor expressions within an interactive systems context.

Second, even though we did find an interaction effect between the posed motor expressions and the imagined problem situations that suggested that incompatibility, rather than congruence can augment creativity (H2) further results can also be constructed to cast some doubt over the validity of these findings. This is mainly because the problem situations did not influence positive and negative emotion (Figure 8, Emotion), despite initially rating the positive situations as more pleasant than the negative situations. It therefore remains unclear whether there was an actual incompatibility between the motor expressions and emotion in this study. This leaves this finding open to alternative explanations, which threatens the internal validity of this particular part of the study. For instance, it could be argued that in this study, the combination of a seemingly incompatible motor expression and problem situation, augmented creativity because people were primed with two different emotion-related concepts, one via the problem situation, and one via the motor expression. This could have made it easier to access more diverse information during idea generation, and therefore have made it easier to come up with more, more diverse, and more original ideas. The latter would be in line with recent findings that priming people with variety augments creativity (e.g. Friedman et al., 2003). Therefore, this result needs to be reproduced with other methods that more reliably induce emotion as a source for incompatibility than the problem situations we used, before any conclusions can be drawn. As such, we believe that the use of incompatibility within an interactive systems context is too premature.

Furthermore, we believe that it is important to point out that no control conditions were used in this study. Neither for the motor expressions (e.g. by asking participants to take on a neutral expression during the task), nor for the imagined problem situations (e.g. by asking participants to imagine themselves in a situation that felt neutral, where they did not feel inclined to react negatively or positively to the situation), nor in a referential manner (e.g. by letting a group of participants not pose and not imagine themselves in a particular problem situation).

First, this limits the results obtained in this study because now we cannot conclude that positive approach expressions upregulate positive emotions or suppress negative emotions, nor that negative avoiding expressions upregulate negative emotions or suppress positive emotions, and influence the link between emotion and creativity accordingly. Thus, we cannot conclude that positive approach expressions, or negative avoiding expressions have both had an actual influence on emotion. This would indeed have required comparison with the use of a neutral arm expression. Rather, we can only conclude that it is likely that there is a difference in the way the posed motor expressions influence the emotion-creativity link.

Second, the lack of a control condition such as a posing a neutral arm expression, and a neutral problem situation also limits conclusions regarding the way incompatibility and congruence function. For instance, a neutral expression paired with a neutral problem situation would have provided a control condition against which the effects of incompatibility and congruence could be assessed. Furthermore, pairing neutral situations with positive or negative expressions, and vice versa, would have offered insight into whether incompatibility really requires a motor expression with an emotional opposite problem situation (e.g. positive approaching expression paired with a negative problem situation), or whether a motor expression that occurs during (problem) situation that elicits no emotional responding (e.g. a positive approaching expression paired with a neutral problem situation) would be sufficient to influence emotion. The latter would have possibly provided valuable insights into the theoretical assumptions that underlie this study. This limits the conclusions that can be drawn from this study's results, but would also be interesting to pursue in future studies.

Third, we also did not test whether imposing motor expressions in itself could be an influence on the emotion-creativity link, or perhaps creativity in general. It is for instance conceivable that the act of imposing a motor expression is detrimental to creativity. Speculatively, imposing an expression may reduce the working memory capacity that is otherwise available to do a creative task, by instructing people to keep the pose (and also the problem situation) in mind (cf. de Dreu et al., 2012). A study where participants would also be assigned to a control group that did not receive instructions to keep a particular expression may have shed light on whether imposing expressions in itself influences creativity for the better or worse. In particular, such a study could provide information on whether the use of motor expressions as a means to influence the emotion-creativity, enables creativity more than not using motor expressions in this particular manner. Such a study could further justify using the function of motor expressions in emotion regulation within an interactive systems context. Nonetheless, our study also justifies further research within an interactive systems context, because it helped demonstrate that imposing motor expressions can in fact help regulate, or at least influence, the emotion-creativity link.

Some of the discussed limitations can also be attributed to our choice to use motor expressions as an independent variable. This introduces the question of how one designs a pose that is neutral. We believe that this is a general limitation of the method used. One that is often encountered in research about the influence of motor expression on emotions (cf. Critchley & Nagai, 2012). Possibly, such issues can be circumvented by using an alternative (experimental) method. For instance, a recent study by Won et al. (2014) used automatic expression recognition software to predict creative task performance. Observing naturally occurring expressions could shed more light on what expressions can be used to influence the emotion creativity link, and perhaps even on what expressions do not influence creativity (positively or negatively), thus possibly even enabling the design of a neutral expression, if such an expression exists.

It is also worth noting that the sample size is not large enough for the used study design, which might make the results more sensitive to individual differences among the participants in relation to the assessed influence on emotion and creativity. Such individual differences may be relevant from two perspectives. First, there is some evidence that indicates that people vary in their sensitivity to emotion-relevant cues from their own body (Andreasson & Dimberg, 2008; Critchley et al., 2004; Ludwick-Rosenthal & Neufeld, 1985; McIntosh, 1996). For instance, people differ in their sensitivity to their own heart-beats, with possible implications for emotional responding (Ludwick-Rosenthal & Neufeld, 1985). It has been suggested that the same could be true for motor expressions (McIntosh, 1996). That is, people may differ in the degree to which they 'listen' to their body and subsequently in the degree to which imposed motor expressions influence their emotions (Critchley et al., 2004). Second, people vary in the degree to which they respond in terms of emotion and motivation to a creative task (Soroa et al., 2015). For instance, some people have more fun when they do a creative task that requires them to find one particular solution, whereas others prefer to think up many diverse ideas. Since our study focuses on the latter, it might be that there were differences among the participants in the degree to which they experienced positive and negative emotions due to individual differences, and subsequently the degree to which these emotions could be influenced by the imposed motor expressions. With a low sample size such as in this study we run the risk that such individual differences are not uniformly distributed over the experimental conditions, which increases the chance of a type I error. This in turn threatens the validly of the results. Therefore, we caution that care must be taken when interpreting and generalizing the results obtained in this study.

Also, we only assessed the participants' positive versus negative feelings as a proxy to emotion. However, from the literature on the emotion-creativity link (section 2.2) we know that different aspects of a positive or negative emotion can influence creativity as well (e.g. differences in levels of arousal (section 2.2.2.1) or differences in motivational direction (sections 2.2.2.2 and 2.2.2.3). Because we did not measure other aspects than the positivity and negativity of the emotions experienced by the participants we cannot rule out that the results of the influence of positive approach expressions were confounded. Therefore further care must be taken to interpret these study results.

The results may also have implications for the way motor expressions can be used to regulate the emotions that augment creativity, and thereby also for the way in which motor expressions can be used to form a theoretical basis for developing interactive systems that make use of the emotion-creativity link. This is because positive approach, rather than negative avoidance expressions, influenced emotion positively in both the positive and the negative problem situation (Figure 8, Emotion). It would have been conceivable that fewer positive emotions would occur in the negative problem situation, because there should be less positive emotions in that situation that the motor expressions should be able to regulate. But because participants experienced no more positive emotions when performing positive expressions in the negative compared to the positive problem situation, we can infer that motor expressions therefore either caused emotion, or regulated the emotions that were caused by something else other than the designed problem situations. The first is unlikely, since recent findings suggest that for motor expressions to influence emotion, an emotional response needs to happen first (Rotteveel et al., 2004). We therefore suspect that the motor expressions helped to regulate the emotions that were caused by something else. More specifically, we suspect that these emotions were caused by the idea generation process itself. This is supported by recent findings that indicate that idea generation typically causes positive emotions (Akhbari Chermahini & Hommel, 2012a). Interestingly, this indicates that when used during idea generation, motor expressions need no external way in which emotions are caused, to exert an influence over emotion, but enable regulation of the emotions that are already spontaneously happening as part of the creative task itself. We believe that this can provide further direction for the way in which interactive systems that make use of the function of motor expressions in emotion regulation to influence the emotion-creativity link can be conceived.

In conclusion, the contribution of this study is a demonstration of two ways in which imposing motor expressions influences emotion and augments creativity. We believe that the results from this study justify further research into using the function of motor expressions in emotion regulation, with the goal to augment creativity, within an interactive systems context. In particular, the use of motor expression congruence, with the emotions that augment creativity, can be used to enable interactive systems with a novel way to regulate emotion, and augment creativity. We believe this is a good first step towards answering *research question RQ1.*

The next step will be to develop further and investigate the mechanisms underlying an interactive system that can effectively make use of the function of motor expressions in emotion regulation. That is, find ways to translate the findings from this study into a viable interactive technology, and reproduce these findings within that context. This will be the focus of study 2 (chapter 5).

5. Study 2: Hacking into the function of motor expressions in emotion regulation to augment creativity

A paper that details the study discussed in this chapter was presented at the Ninth International Conference on Tangible, Embedded and Embodied Interaction, January 2015, Stanford University, CA, USA. This paper is included in Appendix D. A technical report that details early work on the interactive system used in this study is included in Appendix F.

5.1 Introduction

In this chapter, we describe our first novel approach to interactive systems, which is designed to hack into the function of motor expressions in emotion regulation, with the goal to influence emotion in such a way that it can help augment creativity during idea generation and insight problem solving. In particular, this study focuses on explicating the mechanisms underlying the proposed approach. Based on our findings in study 1, and empirical research from psychology about the role of motor expressions in emotion regulation, we suggest that motor expressions can help regulate the positive and negative emotions that are caused during a creative task, and that this can be used to augment creativity during such a task. Based on this argument, we developed a proof-of-concept interactive system that uses embodied interactions that are designed based on the characteristics of motor expressions. This system is designed to help regulate positive emotion during two creative tasks: idea generation, and insight problem solving. To interact with the system, people use arm gestures that are designed based on motor expressions associated either with positive emotion and approach action tendencies, or with negative emotion and avoidance action tendencies. These gestures are choreographed in a way that we suppose enables emotion regulation. The aim of the developed proof-of-concept interactive system is to help explicate the mechanisms underlying the proposed approach in an experimental study. In such an experimental study we demonstrate that using positive approach rather than negative avoidance arm gestures to interact with the system heightens positive emotion, and increases creativity during an idea generation task but not during an insight problem solving task. Note that congruence and *incongruence* is researched here, but in a different manner than in study 1 (chapter 4). In this study incongruence refers to a brief and timely mismatch between a motor expression and events that cause (other) emotions, which is assumed to *suppress* an emotional response. This is different from the form of incongruence (i.e. incompatibility) investigated in study 1 (chapter 4). Finally, the contribution of this study is a demonstration that an interactive system can be designed to use the function of motor expressions in emotion regulation to help people perform better on creative idea generation tasks, but not on verbal insight problem solving tasks (*research objective O2*). We assume that this demonstration, at least for idea generation tasks, positively answers *research question RQ1*.

5.2 Regulating emotion

As was described in chapter 4 (section 4.2), motor expressions play a role in emotion regulation. *Congruence* between a motor expression and an emotion provides positive feedback to that emotion, which increases the disposition to have, and the intensity of that emotion. A brief incongruence can introduce negative feedback, which decreases the disposition to have, and the intensity of an emerging emotion, thereby introducing *suppression* of an emotional response. However, for an interactive system to make use of the function of motor expressions in emotion regulation, there may be certain additional *conditions* that need to be met (Figure 9).

We hold the view that emotions are caused by personally relevant events that happen in an individuals' environment (section 2.2). Hence, we assume that motor expressions typically do not cause emotion, but rather regulate existing emotion (Roseman, 2004). For instance, approach arm movements influence emotion when people appraise the emotion of a face, but not when they evaluate its spatial properties (Rotteveel et al., 2004). Of course, this does not mean that motor expressions cannot have a more bottom-up effect (Carney et al., 2010; 2015). But see (Pfaf et al, 2014; Price & Harmon-Jones, 2015; Roseman, 2004). A consequence of this assumption is that motor expressions need to happen around the same time an emotion is being experienced, to enable motor expressions' function in emotion regulation to improve its effectiveness (Figure 9). That is, an emotion needs to happen before motor expressions can help to regulate that same emotion.

Motor expressions must also associate somehow with the structure of an emotional response, in order to regulate that same emotion. For instance, when predicting the cause of future problems and opportunities, adopting an angry or sad pose only influences the prediction of future problems, not opportunities (study 4 in Keltner et al., 1993). This corresponds to the cognitive appraisal processes that are involved in these emotions, i.e. negative emotions are typically caused when a problem is encountered

(Scherer, 2009). As such, we assume that a motor expression also needs to be meaningful to the structure of the processes that cause motion. We assume that these conditions need to be met if we want to enable an interactive system to use the function of motor expressions in emotion regulation.

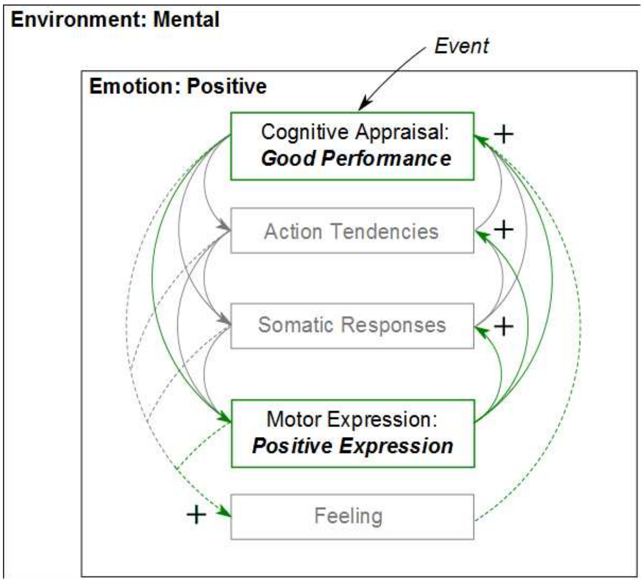

Figure 9 Schematic (revised) of the function of motor expression congruence in emotion regulation. An event in the environment causes emotion (e.g. a positive emotion) via cognitive appraisal processes (e.g. that one is performing well), by feeding forward into the emotion components, including motor expressions (left green arrow). Congruence of the motor expressions (e.g. a positive expression such as a smile or a positive gesture) with the emotion (e.g. a positive emotion) increases the intensity of that emotion via positive feedback (+). The motor expression also feeds forward into shaping an individual's feelings (green dashed arrows).

It could be argued that *Interactive systems* in which motor expressions play a role, are relatively common. For instance, affective mirrors (section 2.3.1.3) and mimicking social interactions (section 2.3.1.4) are likely to, at least in part, make use of the function of motor expressions in emotion regulation, due to people's tendency to mimic each other's (and for instance a robots') expressions. However, interactive systems that have been explicitly designed to make use of the function of motor expressions in emotion regulation, are scarce. One project that uses electrical stimulation of the muscles involved in smiling as a therapeutic tool appears to enable emotion related coping (Zariffa et al., 2014). Another project that uses physical positioning by means of an automated chair, has been used to impose postures that are congruent with movie scenes, which increased the perceived intensity of some positive movie scenes (Kok & Broekens, 2008). Embodied interactions have also been designed based on characteristics of motor expressions (postures) that associate with high and low power (Isbister et al., 2012). Used as a way to interact with a mathematics game, it was hypothesized that this would help to combat math anxiety, but no results on this have been published until now. Furthermore, there are reports of heightened emotional engagement in computer games that enable or impose motor expressions during interaction (Bianchi-Berthouze, 2013; Bianchi-Berthouze et al., 2007; Isbister et al., 2011). For instance, the use of game controllers that impose or allow users to express themselves physically, is thought to enable them to experience the role they play in a game more fully, at least partially by unlocking the function of motor expressions in emotion regulation (Bianchi-Berthouze, 2013). This indicates that interactive systems can be designed to make use of the function of motor expressions in emotion regulation. However, no interactive systems currently exist that explicitly attempt to hack into the function of motor expressions in emotion regulation (section 2.3.3.1), to influence the emotion-creativity link. Nor do any systems exist that have been shown to enable this by means of embodied interactions. In this chapter we develop such a technology.

In this study we will attempt to enable the regulation of positive emotion by designing arm gestures based on expressions of positive emotion and approach action tendencies, and negative emotion and avoidance action tendencies.

5.3 Regulating emotion to augment creativity

To develop a theoretical basis for an interactive system that makes use of the function of motor expressions in emotion regulation, to influence the emotion-creativity link, we bring together assumptions about the role of motor expressions in emotion regulation, with assumptions about the way positive and negative emotions are caused during a creative task (Figure 10).

Based on the above, as well as the results and discussion from study 1 (chapter 4), we believe that motor expressions can help to regulate the emotions that are caused by a creative task, in a manner that can be used to influence the emotions that augment creativity. We assume this is conditional upon a) the creative task causing emotion, b) using a motor expression at the moment this emotion is caused, in a manner that is meaningful within the structure of the caused emotion, and c) using motor expressions that associate with those aspects of an emotion that can augment, rather than diminish creativity.

For instance, generating diverse ideas can in itself cause positive emotion, e.g. generating many and diverse ideas may be appraised as indicating good performance (cf. Akhbari Chermahini & Hommel, 2012a; Brunyé et al., 2013; Zenasni & Lubart, 2011). Motor expressions can be used to regulate these emotions when they happen simultaneously with the emotion that is caused by the creative task, i.e. at the moment a creative task causes an emotion (section 5.2). Motor expressions that are congruent with that emotion can augment that same emotion, whereas motor expressions that are incongruent with that emotion can suppress, and therefore diminish, that same emotional response (section 4.2). Because we know that positive, rather than negative emotion augments creativity during idea generation (section 2.2.1.1); expressions that associate with positive emotions can help regulate these emotions in a manner that augments or diminishes creativity. Preliminary evidence for this possible mechanism was already found in study 1, where we showed that positive approaching, rather than negative avoiding motor expressions, augmented creativity, via their influence on positive emotion during an idea generation task (chapter 4). We therefore believe that an interactive system can be designed to hack into the function of motor expressions in emotion regulation, to enable regulation of the emotions that are caused during a creative task. This is what we explore in this study.

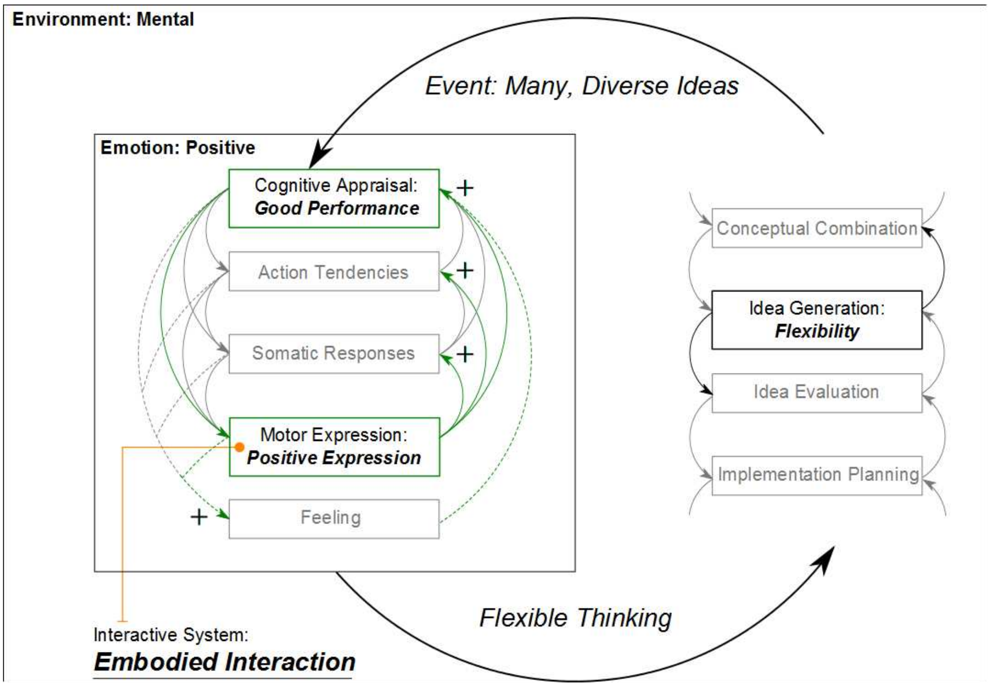

Figure 10 A schematic of our use of the function of motor expressions in emotion regulation to influence the emotion-creativity link. The figure shows the function of motor expression congruence (+) in regulating a positive emotion (left, green arrows), the

influence of positive emotion on creativity during the idea generation step in the creative process (right), and the way the interactive system makes use of this relationship to influence the emotion-creativity link (bottom-left).

In section 2.3.3.2 we discussed possible limitations of interactive systems that influence the emotion-creativity link. The gist of this discussion was that in order to be effective, the way such an interactive system influences emotion should be meaningful within the context of a creative task. We believe that *interactive systems* that use the function of motor expressions to help regulate, rather than cause emotion, is one possible approach that can tackle these limitations. If the interactive system helps to control and modify the emotions that happen spontaneously in a creative task, rather than causing any new emotions, then the emotions that are caused, are necessarily meaningful to the creative task. This circumvents the need of the way the interactive system influences emotion, to be meaningful within the context of a creative task. Instead, the motor expressions must be meaningful to the emotional responses that happen during the creative task. This implies that the effectiveness of such a system is dependent on the limitations that are posed by the conditions under which motor expressions can help regulate emotion. The latter, we have addressed in the paragraphs above (section 5.2). For these reasons, we believe that hacking into the function of motor expressions in emotion regulation can be an effective approach to interactive systems that attempt to hack into the emotion-creativity link.

To further develop and investigate this approach, we will focus on using arm gestures that associate with positive emotion and approach action tendencies, or arm gestures that associate with negative emotions and avoidance action tendencies, as a means to interact with a system during idea generation and insight problem solving.

5.4 Interactive system

To evaluate our until now still theoretical approaches, we have developed a 'proof of concept' interactive system that: 1) uses arm gestures designed based on motor expressions that associate with positive emotion and approach tendencies, and with negative emotion and avoidance tendencies; and 2) uses a choreography of these interactions, that we suppose, meets the conditions that are necessary for motor expressions to help regulate emotion.

5.4.1 Arm gestures

For our experimental purposes we designed two arm gestures, a positive approaching, and a negative avoiding arm gesture. The *positive approach arm gesture* used to interact with our system is arm flexion, which links to approach tendencies (Centerbar et al., 2008; Friedman & Förster, 2002), and is characterized by a centrifugal movement that starts at the side of the body and moves with a curve toward the heart, executed with a balanced level of muscle tension, which also links to positive emotion (Dael et al., 2012; Scherer, 2009) (Figure 11a). This arm gesture is designed to increase positive emotion, when it occurs, via congruence, and decrease negative emotion via suppression. The *negative avoidance arm gesture* is arm extension, which links to avoidance tendencies (Centerbar et al., 2008; Friedman & Förster, 2002), and is characterized by a centripetal movement that starts at the side of the body, then moves to the chest (diaphragm), and then outwards away from the body, using a slightly increased level of muscle force, which also links to negative emotion (Dael et al., 2012; Scherer, 2009) (Figure 11b). This arm gesture is designed to increase negative emotion when it happens via congruence, and decrease positive emotion via suppression.

5.4.2 Choreography of interaction

To enable emotion regulation we designed a 'choreography' based on the conditions that, we suppose, enable the designed arm gestures to help regulate the emotions that are caused by a creative task. We conjecture that the arm gestures need to happen at the same time as any emotions caused during the creative task; and assume that emotions tend to happen right after an idea is generated or an insight problem is answered. These are events at which people might appraise their own creative task performance (e.g. positive: this idea was very good, or negative: again an idea of insufficient quality). If these caused emotions are positive and involve approach action tendencies, or are negative and involve avoidance action tendencies, we suppose that the designed arm gestures can help regulate these emotions in an intended direction, and thereby influence creativity (Figure 10). To implement this, the arm gestures are consistently used immediately after people generate an idea or solve an insight problem.

5.4.3 Recording ideas

To test whether the designed arm gestures used with our proposed choreography of interaction enable us to hack the function of motor expressions in emotion regulation, we developed a Dictaphone, that enables users to record their ideas or solutions by using the arm gestures.

The arm gestures are used to record an idea or solution just after it is generated. To start recording, the user performs the arm gesture; to keep recording, the user keeps the end position of the gesture stable (during which time ideas or problem solutions can be recorded by speaking these out loud into a microphone); and to stop recording the user releases the gesture. For the insight problem solving task, releasing the arm gesture would also present the next insight problem. To meet the basic demands of the creative tasks we present an image of the object AUT during that task, and the insight problems that need to be solved during the insight problem solving task on the screen (Figure 11). Whenever the arm gesture is used to record an idea, visual feedback is also given on the screen by means of a blinking recording sign (• rec).

To enable the Dictaphone to automatically trigger the recording, we use a Kinect sensor and a mechanical myograph in a classification setup. We capture the relative angles between the shoulder and the elbow, and the elbow and the wrist of the dominant arm with the Kinect; and muscle force from the biceps, triceps, flexor capri, and extensor capri is calculated by taking the root mean square of the signal of a mechanical myograph (Figure 11). We assume this captures the motor expression characteristics based on which the gestures were designed. See Appendix F for further details. We trained four hidden Markov models to classify: no gesture; the start of the gesture; keeping the gesture; and releasing the gesture, using the Viterbi algorithm (Rabiner, 1989). The parameters were set using grid search (Pedregosa et al., 2011). Data used to train the model was obtained by letting the user perform their instructed arm gestures. These were annotated by the researcher. Classification is done using ARGMAX of a sequence on the log probability under each model (Rabiner, 1989). The ability of the trained models to classify the gestures was assessed right after that. In case of insufficient performance, i.e. f_1-score<0.95 (Powers, 2011), the researcher switches to a Wizard of Oz approach, i.e. the researcher triggers the recording him or herself when the user does the arm gesture.

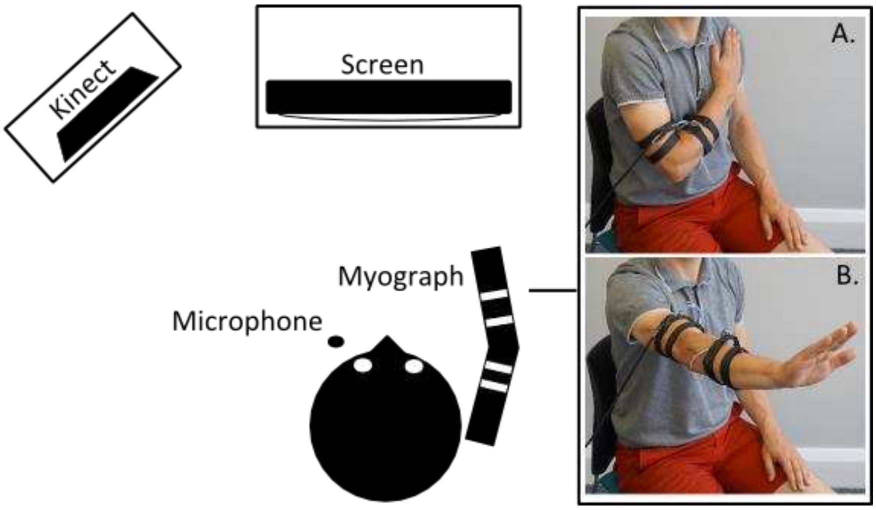

Figure 11 Illustration of the setup (left), and the end position of the A) positive approach and B) negative avoidance gesture.

5.4.4 Hypotheses

To put our theoretical conjectures and the developed proof-of-concept interactive system to the test, we experimentally test the four hypotheses shown in Table 4.

#	Hypothesis
H1	*Positive, rather than negative emotion associates with augmented creativity.*
H2	*Using positive approach rather than negative avoidance arm gestures to interact with a system augments positive emotion.*
H3	*Using positive approach rather than negative avoidance arm gestures to interact with a system augments creativity.*
H4	*Using positive approach rather than negative avoidance arm gestures to interact with a system augments creativity via its influence on the emotion-creativity link.*

Table 4 Hypotheses for study 2.

5.5 Method

To test the hypotheses and thereby evaluate experimentally the interactive system, we used a between-subjects experimental design, with people in one group using the positive approach arm gesture, and people in the other group the negative avoidance arm gesture, to interact with the system. We favoured the between- over a within-subjects design because it enabled us, given limited resources, to test the interactive system with two different creative tasks. Moreover, we chose to not counterbalance the order of the creative tasks because we prioritized results for the idea generation task, which builds upon our previous work (chapter 4), and aligns with the scope of the research presented in this thesis (section 1.3), over the insight problem solving task, which we consider more of an exploration.

5.5.1 Participants

In total 37 people participated in this study (Females=17, Males=20, M_{age}=32, SD_{age}=7, Left handed=7, Right handed=30), with 19 participants using a positive approach and 18 participants using the negative avoidance arm gesture. We switched to a Wizard of Oz mode with 8 participants in both experimental conditions. The participants were students and employees of City University London.

5.5.2 Materials and measurements

5.5.2.1 Creative tasks

We embedded two creative tasks in our Dictaphone application.

Task 1 was the AUT, which was used to gather data about creativity during idea generation (section 3.3.1). Participants were instructed to "*…come up* *with as many, diverse, and original uses for a common object as you can*", within 5 minutes. The common object used was a brick. To help ensure that the AUT emulates the idea generation step in the creative process more accurately, we emphasized the generation of original ideas, which is the same approach we detailed previously in section 4.5.2.1.

Task 2 was a verbal insight problem solving task (de Bono, 1970; Dow & Mayer, 2004). Insight problems are verbal puzzles that have only one correct answer, but cannot easily be solved using the details provided in descriptions of the problems themselves, nor by step-by-step logical thinking (e.g. Q: Is it legal for a man to marry his widow's sister? A: No, he's dead). The ability to do this quickly and correctly is thought to underlie general creative ability (de Bono, 1970). We instructed participants to *"…solve as many insight problems you can"*, within 10 minutes, but also mentioned to try *"…not to spend more than half a minute on each problem."* The latter was added to make sure that people would use the interactive system often enough for the arm gestures to have an influence on emotion.

5.5.2.2 Assessment of creativity

To assess creativity based on the data gathered using the AUT we used the objective scoring method (section 3.3.2). That is, we counted the number of ideas that a participant generated (*fluency*), the number of semantic concepts used in the generated ideas (*flexibility*), and the statistical infrequency of the participants' ideas, given the ideas generated by all the participants (*originality*). Originality was assessed by counting the ideas of which there were no more than two instances in the whole sample (16% of the total amount of ideas in this study) (cf. Silvia et al., 2008). To help correct for the confounding influence of fluency on originality, we used the percentage score (Plucker et al., 2011). That is, we divided the number of original ideas by the total number of ideas generated during a task. The percentage score improves the construct validity of the way originality is assessed, but also the external validity of results obtained with this measure, because it corrects for people who are (naturally) highly fluent in their responses (Plucker et al., 2011; 2014).

To assess creativity during the insight problem solving task we calculated the percentage of correctly solved insight problems by dividing the amount of answered problems by the amount of correctly answered problems (39% of the total amount of answered insight problems were correct) (de Bono, 1970; Dow & Mayer, 2004). We assumed that a percentage score would support the construct and external validity of these results, for the same reasons as outlined in the above paragraph (cf. Plucker et al., 2011; 2014). That is, by correcting a possible confounding influence of the amount of problems solved on the amount of problems that were solved correctly.

Creativity was assessed for both tasks by the researcher after the study ended.

5.5.2.3 Assessment of emotion

Participants self-reported their emotional state on a Likert scale from negative to positive emotion after each task (1=very negative, 9=very positive) (section 3.3.3). We used the more general positive versus negative because we don’t know exactly what aspects of positive and negative emotion the motor expressions may regulate. Asking people to self-report unpleasantness-pleasantness for instance, such as we did in study 1 (section 4.5.2.3), might exclude other aspects of emotion that are associated with its positive and negative feeling component (see Scherer, 2005). To further support self-report we used the same approach we detailed previously in section 4.5.2.3.

5.5.2.4 Manipulation checks

Several checks were carried out to support the internal validity of the study design (section 3.3.4). To assess any possible alternative causes of variation by the designed arm gestures, we asked people to self-report on: 1) the pleasantness and unpleasantness of the arm gestures themselves (1=unpleasant, 9=pleasant), 2) the physical effort needed to perform the arm gestures (1=little effort, 9=a lot of effort) and 3) the degree of freedom with which the arm could be moved given that there were four sensor units strapped to their arm (1=difficult to move, 9=easy to move) all by using 9-point Likert scales.

5.5.3 Procedure

Upon arrival, each participant was introduced to the study, its procedure, and information was provided about the myograph sensors. The latter was to get the participants acquainted with the equipment used, so that they felt comfortable using this equipment. After this, informed consent was signed, and we asked the participants to fill in some personal details (age, gender). Right thereafter we strapped the myograph sensors to the participants' dominant arm, and calibrated the Kinect sensor. After we ensured that the sensors were placed correctly, the participants were given instructions to use either the positive approach or the negative avoidance arm gesture as an embodied interaction throughout the study. That is, use the instructed arm gesture to record their ideas and problem solutions during the creativity tasks. These instructions were practiced together with the researcher until both researcher and participant were confident that the sensors and embodied interactions could be used as instructed. After this, we were ready to start the recording of the arm gestures to train the arm gesture recognition capabilities of the system. To do this, a program was used that initiated a countdown for each part of the gesture (gesture, keeping the gesture endpoint, releasing the gesture, and no gesture). After each countdown the participant would do the instructed part of the gesture, which was annotated by the researcher in real-time. This gesture was done 15 times following this procedure to collect (a sufficient amount of) data based on which the interactive system could generate models that could classify the gestures (in total this took 5 minutes). In case the collected data did not lead to a sufficient classification accuracy (f_1-score<0.95), we switched to a 'Wizard of Oz' approach before the two creative tasks started. In the former case, the researcher would be notified by the interactive system immediately. When the latter happened, the researcher would also notify the participant to ensure that the participant would not start to suspect that the system was controlled by the researcher, while earlier information about the study may have suggested otherwise. After this, participants were offered the chance to practice using the interactive system to record ideas or problem solutions (without the creative tasks). After this, the instructions were provided for the AUT (task 1) and the insight problem solving task (task 2). Participants then did the AUT (5 minutes). That is, they used the interactive system to record the ideas they generated. After the AUT ended, the participants rated their emotions. Then, participants used the interactive system to perform the insight problem solving task (task 2) (10 minutes), after which they again rated their emotions, but now also rated any manipulation checks. The participants were asked to remove the myograph sensors, were offered an opportunity to share their thoughts about the study, and were debriefed, after which they received a £10 voucher for a large online retailer for their efforts. A graphic representation of the procedure is presented in Figure 12.

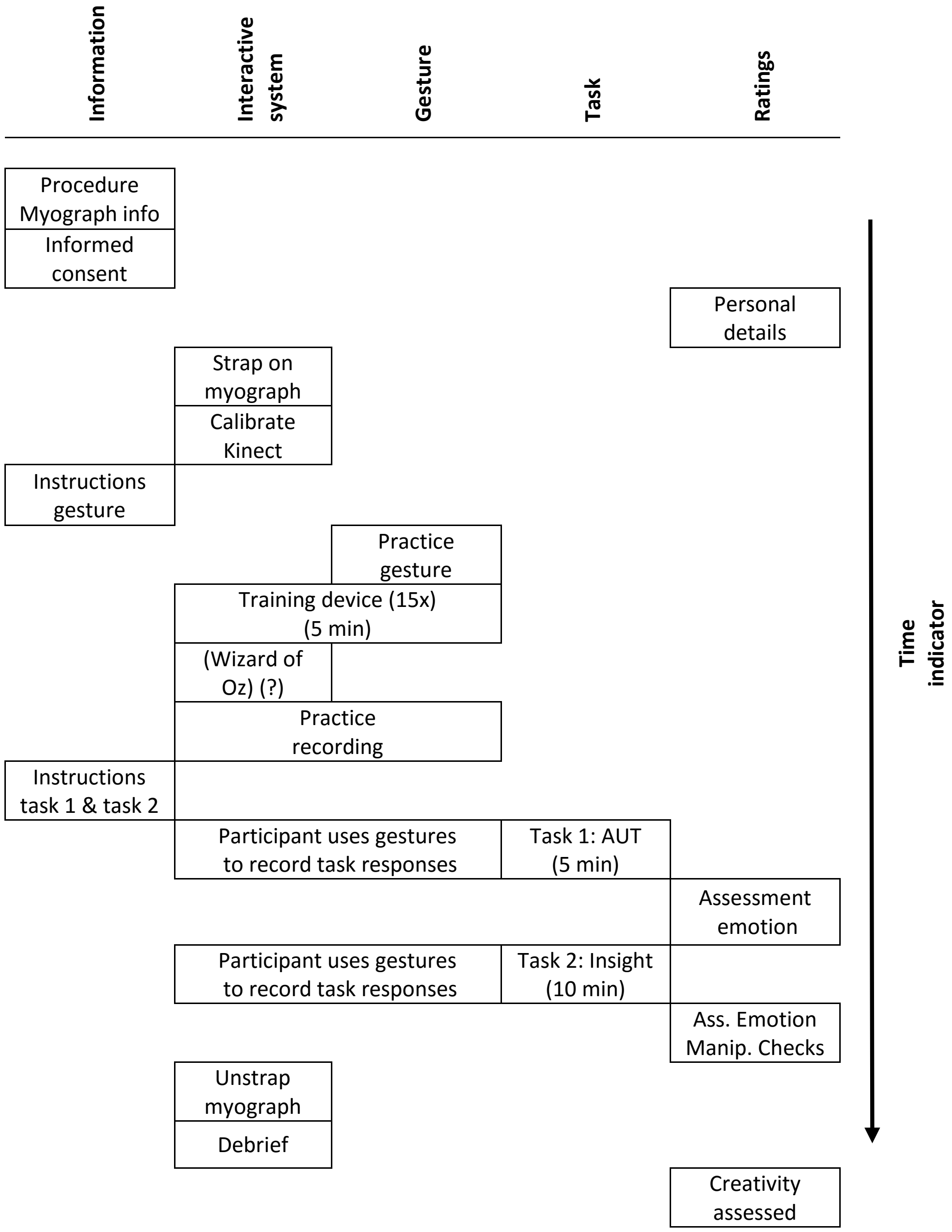

Figure 12 Graphic representation of the order and timing of information, activity related to the use of the interactive system, use of the gestures and thus an indicator of when emotions may have been influenced, the tasks performed, and the ratings used in the procedure.

5.6 Results

We first performed several checks that could possibly explain any variation caused by the arm gestures, in a different way than we intended, by submitting the manipulation checks individually as DVs to a one-way ANOVA, with the arm gestures as the IV. The results showed no significant effect of the arm gestures on the pleasantness or unpleasantness of the arm gestures themselves ($F(1, 35)=0.38$, $p=.545$), the physical effort needed to do the arm gestures ($F(1, 35)=0.03$, $p=.866$) and the freedom with which the arm could be moved ($F(1, 35)=0.23$, $p=.638$). This suggested that any possible effects of the arm gestures on emotion and creativity was unlikely to be due to differences between the gestures with regard to the above variables.

5.6.1 Task 1: Idea generation

To test whether there was an association between emotion and creativity across the experimental conditions during idea generation, we correlated the DVs fluency, flexibility, and originality, with the self-reported emotion ratings (Table 5). The results suggested that there was no significant correlation between fluency and emotion, but there was a significant positive correlation between flexibility and emotion, and a significant positive relationship between originality and emotion. These findings suggest that positive, rather than negative emotion associates with creativity during idea generation. This supports hypothesis H1 within the context of creative idea generation.

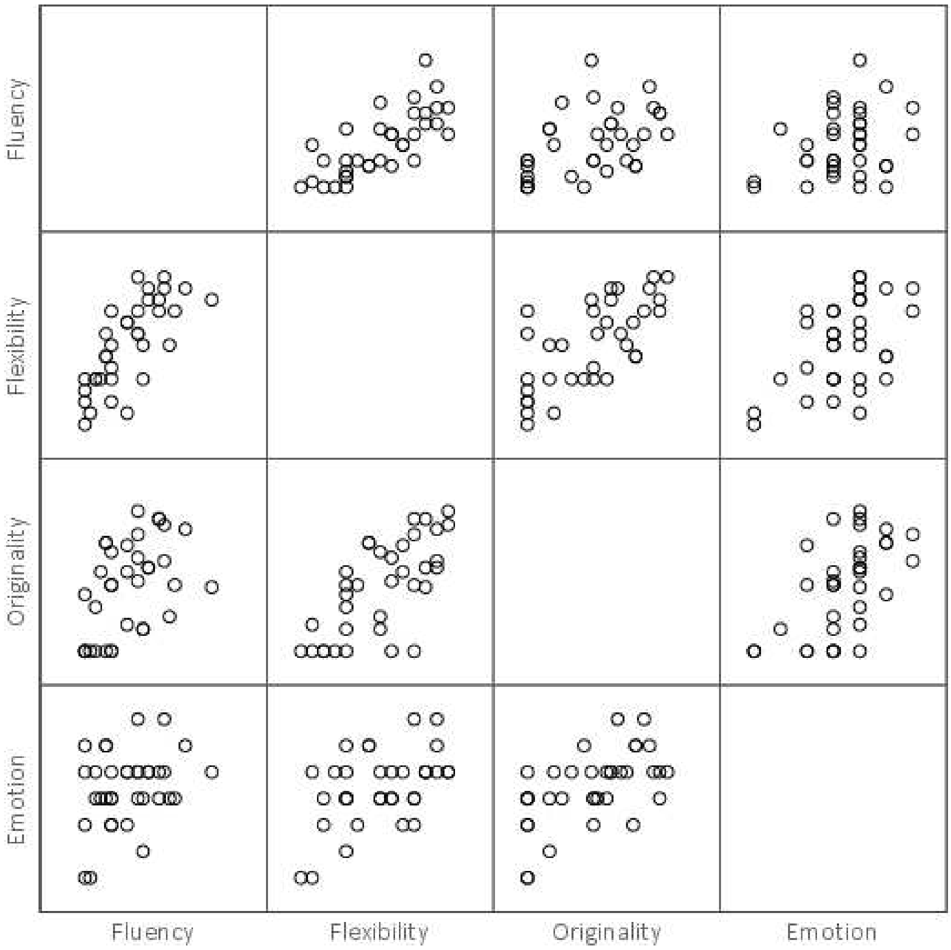

Figure 13 Scatterplot matrix of the dependent variables fluency, flexibility, originality, and emotion.

DV	1.	2.	3.	4.
1. Fluency	-			
2. Flexibility	.739**	-		
3. Originality	.500**	.684**	-	
4. Emotion	.314	.493**	.574**	-

*Table 5 Pearson correlation coefficient for the DVs fluency, flexibility, originality, and emotion. ** is p<.005.*

IV / DV	Positive approach	Negative avoidance
Fluency	17.32 (4.85)	13.18 (6.55)
Flexibility	10.95 (3.01)	7.00 (3.41)
Originality	0.24 (0.08)	0.08 (0.10)
Emotion	6.89 (1.24)	5.81 (1.34)

Table 6 Means and standard deviations (between parentheses) for fluency, flexibility, originality, and emotion (DVs), for each of the arm gestures (IV).

To test whether there was an effect of the way the interactive system was used on emotion and creativity, we submitted the measured emotion, fluency, flexibility, and originality individually as a DV to a one-way ANOVA, with the arm gestures as the IV. The descriptive statistics are presented in Table 6, a scatterplot matrix with the dependent variables is presented in Figure 13.

The results suggested that there was a significant effect of the arm gestures on emotion ($F(1, 34)=5.97$, $p=.020$, $\eta^2=.153$). These results indicated that, during the idea generation task, positive approach arm gestures, rather than negative avoidance arm gestures augmented positive emotion. This supports hypothesis H2 within the context of creative idea generation.

The results also suggested that there were significant effects of the arm gestures on fluency, $F(1, 34)=4.71$, $p=.045$, $\eta^2=.122$, flexibility, $F(1, 34)=13.62$, $p=.001$, $\eta^2=.286$, and on originality, $F(1, 34)=25.52$, $p<.001$, $\eta^2=.430$. These results indicated that, during the idea generation task, positive approach arm gestures, rather than negative avoidance arm gestures augmented creativity. This supports hypothesis H3 within the context of creative idea generation.

Because the results from the ANOVAs suggest that using positive approach, rather than negative avoidance arm gestures to interact with the proof-of-concept system influences both emotion and creativity individually, and the correlations indicate that there was a relationship between the creativity variables flexibility, originality and emotion across the experimental conditions, we assume that the interactive system can be used to influence the emotion-creativity link effectively during creative idea generation. This supports hypothesis H4 within the context of creative idea generation.

5.6.2 Task 2: Insight problem solving

Before we analysed task 2 we checked whether the influence on emotion in task 1 carried over into the results of task 2. Results of a Pearson correlation showed no significant correlation between the emotions reported after task 1 and the percentage of correct answers ($r=.064$, $p=.715$), nor did the results show a significant correlation between emotion reported after task 1 and emotion reported after task 2, ($r=.307$, $p=.073$).

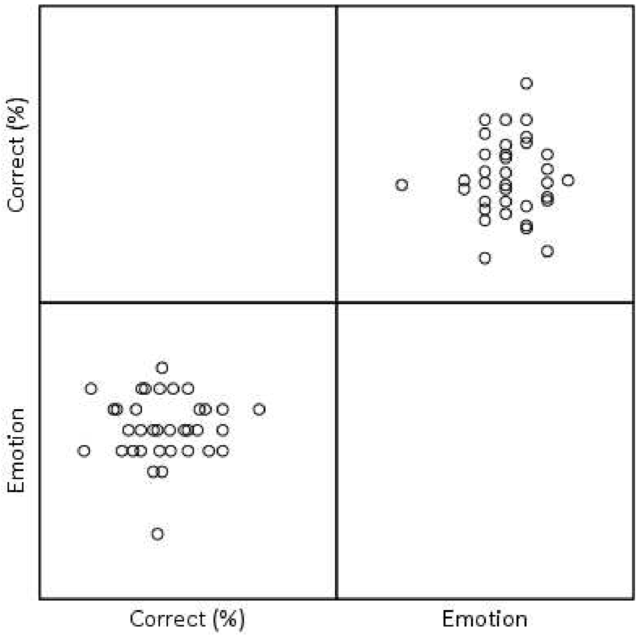

Figure 14 Scatterplot matrix of the dependent variables correct (%) and emotion.

To test whether there was an association between emotion and creativity across the experimental conditions, during insight problem solving, we correlated the dependent variable emotion with the percentage of correctly answered insight problems. Participants on average answered 15.47 (SD=6.94) insight problems. The results showed no significant correlation between the percentage of correct answers and emotion (r=.076, p=.659). These findings suggest no association between positive emotion and insight problem solving. This does not support hypothesis H1 within the context of insight problem solving.

IV / DV	Positive approach	Negative avoidance
Correct (%)	0.44 (0.19)	0.33 (0.17)
Emotion	6.25 (1.52)	5.81 (1.64)

Table 7 Means and standard deviations (between parentheses) for the percentage of correctly answered insight problems and emotion (DVs), for each of the arm gestures (IV).

To test whether there was an effect of the way the interactive system was used on emotion, and on creativity individually, we submitted the emotion, emotion′, the percentage of correctly answered insight problems individually as a DV to a one-way ANOVA, with the arm gestures as the IV. The descriptive statistics are presented in Table 7, a scatterplot matrix with the dependent variables is presented in Figure 14.

The results suggested that there was no significant effect of the arm gestures on emotion, $F(1, 35)=0.69$, $p=.413$. These results indicated that, during insight problem solving, there were no directly observable differences in the effects of positive approach and negative avoidance arm gestures on emotion. This also does not support hypothesis H2 within the context of insight problem solving.

However, the results did suggest that there was a significant effect of the arm gestures on the percentage of correctly answered insight problems, $F(1, 35)=5.09$, $p=.030$, $\eta^2=.127$. These results indicated that, during the insight problem solving task, positive approach arm gestures, rather than negative avoidance arm gestures augmented creativity. This does support H3 within the context of insight problem solving.

Because the results from the ANOVAs suggest that using positive approach, rather than negative avoidance arm gestures to interact with the proof-of-concept system does not influence emotion, but does influence creativity individually, and the correlations indicate that there was no clear relationship between the percentage of correctly answered insight problems and self-reported emotion across the experimental conditions, we assume that the interactive system in its current state cannot be used to influence the emotion-creativity link effectively during verbal insight problem solving. This does not support hypothesis H4 within the context of insight problem solving.

5.7 Discussion

The findings in our study demonstrate that an interactive system can be designed to hack the function of motor expressions in emotion regulation to help people perform better on certain creative tasks (*research objective O2*).

The findings suggest that positive, rather than negative emotion, associates with augmented creativity during idea generation but not during insight problem solving (H1). This in itself is nothing new (sections 2.2.1.1, 2.2.1.2). However, it shows that there was a relationship between emotion and creativity in the data that the interactive system could have influenced. The findings further suggest that when positive approach rather than negative avoidance arm gestures are used with our interactive system, positive emotion is augmented, during idea generation (H2). However, we did not find clear effects of the motor expressions on emotion during insight problem solving. This indicates that embodied interactions designed based on motor expressions, and used to interact with our system, can help to regulate emotion during idea generation. However, support for its effectiveness during insight problem solving was weaker. Using positive approach rather than negative avoidance arm gestures with our interactive system, augments creativity during an idea generation task but not during an insight problem solving task (H3). This indicates that embodied interactions designed based on motor expressions, and used to interact with our system, can augment creativity during idea generation. These findings indicate that during idea generation the use of positive approach rather than negative avoidance arm gestures, augments creativity via its influence on the emotion-creativity link (H4). That is, the effects of the interactive system on emotion (H2) and on creativity during idea generation (H3), can be explained by the effects of the system on the emotion-creativity link (H1).

There were of course also limitations to the study. Most notably, these were introduced by not including a control condition. No control conditions were used for the embodied interactions (e.g. by using a more neutral expression to record ideas or problem solutions), nor did we enable a comparison between the used embodied interactions and not using any embodied interactions at all (e.g. using automatic speaker recognition to automatically start and stop the audio recorder when it 'hears' speech, or when it doesn't 'hear' someone speaking anymore).

First, and similar to the limitations in study 1 (chapter 4), not using a neutral embodied interaction limits the results that are obtained in this study because on the basis of the current results we cannot argue that positive approach gestures boost positive emotions (congruence) or suppress negative emotions (incongruence), nor that negative avoiding gestures upregulate negative emotions (congruence) or suppress positive emotions (incongruence), and thereby influence the link between emotion and creativity accordingly. As such, we cannot conclude that our use of positive approach gestures, or negative avoiding gestures both have had an influence on emotion, and thus not whether congruence or incongruence was responsible for the effects observed. This requires comparison the use of a neutral arm gesture. Such a neutral expression can possibly be uncovered by a study observes naturally occurring expressions during a creative task (cf. Won et al., 2014). In such a study, the motor expressions observed that do not associate with particularly high or low task performance, and do not associate with emotional responding, could perhaps be considered a neutral expression. Based on this knowledge a reliable neutral embodied interaction could possibly be designed, enabling the use of a control condition. However, since the present study lacks this knowledge, and thus a control, we can only conclude that it is likely that there is a difference in the way the using embodied interactions influence the emotion-creativity link.

Second, we also did not test whether the use of the embodied interactions in itself could have been an influence on creativity. For instance, as argued in study 1 (section 4.7), it might be the case using embodied interactions is in itself detrimental to creativity, because it might burden working memory, which would be unburdened and thereby conducive to creativity when compared to not using embodied interactions with the interactive system (cf. de Dreu et al., 2012). Although this could help justify the use of embodied interactions as a means to help augment creative thinking, we believe that such a study is outside the scope of this thesis. Rather, we aim to uncover the mechanisms based on which interactive systems can be designed to make use of the emotion-creativity link effectively. Thus, the study design aligns with the goals set for this thesis (section 1.2). However, studying whether or not embodied interactions designed based on motor expressions can be used to enhance creativity, when compared to not using such embodied interactions is likely to be invaluable to justify the use of this particular approach to interactive systems in practice. Therefore, it may be an interesting opportunity for future research.

Just like in study 1 (chapter 4) we only assessed the participants' positive versus negative feelings as a proxy to emotion. However, literature review on the emotion-creativity link (section 2.2) also showed that there exist other aspects of a positive or negative emotion that can influence creativity during idea generation and insight problem solving. This is particularly relevant because the arm gestures used in our study involved expressive features that explicitly associate with approach and avoidance action tendencies. Even though we have argued that their effect on emotion was assumed to target the regulation of positive and negative emotion, we cannot rule out that there were differences between the experimental conditions that were due to these approach and avoidance tendencies only. With regard to developing and explaining the mechanisms that underlie the effectiveness of the developed approach, the results obtained may be confounded. Therefore, we advise caution when interpreting this particular aspect of the study results.

The results also point toward interesting limitations for the possible *effectiveness* of our approach. Whereas during idea generation the results were clear, during insight problem solving there were less pronounced or even non-existent relationships between the arm gestures, emotion, and creativity. It might be that other factors, which we did not measure, had a stronger influence on emotion during insight problem solving. However, another explanation could be that the used arm gestures are only effective for a limited amount of time due to habituation (cf. Stepper & Strack, 1993). We cannot rule out the latter because we did not randomize task order. This does however, suggest that more work is necessary to explicate the temporal limitations that are inherent using the function of motor expressions in emotion regulation as a means to target the emotion-creativity link.

There was also another possible limitation for the *effectiveness* of our approach. People who used positive approach arm gestures reported more positive emotion than the people who used the negative avoidance arm gestures, but the latter people were still positive on average. It could well be that the used creative tasks did not generate sufficient negative emotion for the arm gestures to help regulate these emotions, and all that we found was that positive approach arm gestures increase positive emotion, and negative avoidance arm gestures suppress positive emotion. That would for instance require tracking emotions automatically and possibly another way of choreographing interactions than we used in this study (e.g. Savva et al., 2012); or at least the use of creative tasks of which we know in advance cause negative emotions, or positive emotions, in a manner that can be controlled experimentally. Therefore we cannot know from the results obtained from this study whether the function of motor expressions in emotion regulation can be hacked for emotions other than positive ones. Previous attempts at hacking the function of motor expressions in emotion regulation suffered from similar complications (Kok & Broekens, 2008; Zariffa et al., 2014), which suggests variations in the emotions that motor expressions can regulate, at least, within the use of our interactive system (cf. Gross, 1998).

It is also worth noting that the sample size used in this study is on the low side for the used study design, which might make the results more sensitive to individual differences among the participants in relation to the assessed influence on emotion and creativity, and therefore increase the chance of a type I error. We would like to point out that these particular individual differences that may play a role in this increased risk at a type I error are the same as we discussed in the discussion section of study 1 (section 4.7). This includes likely individual differences in the degree to which people are sensitive to motor expressions (Andreasson & Dimberg, 2008; Critchley et al., 2004; Ludwick-Rosenthal & Neufeld, 1985; McIntosh, 1996). For instance, Gross & John (2003) showed that there exist individual differences in the effectiveness with which people use motor expressions to suppress (via incongruence) negative emotions. Furthermore, individual differences exist in the way people mobilise emotional, motivational, and cognitive changes in response to different creative tasks (Soroa et al., 2015). For instance, some people have more fun doing a task where they have to solve one complex problem creatively, while others enjoy generating many different solutions to a problem quickly. Aside from an increased chance of a type I error, this also threatens the external validity of any conclusions that were drawn based on the study results. That is, we don't know if this approach to interactive systems will work for anyone, during any creative task. As such, future studies that would focus on justifying the use of motor expressions in an interactive systems context, rather than focusing on uncovering the mechanisms underlying such systems (such as we do), would do well to include individual difference measures (e.g. Soroa et al., 2015).

Furthermore, we believe it is good to reiterate that the way the interactive system was made was focused on testing the hypotheses within the constraints of the methodology that we chose to use (section 3.2.2). Therefore, we did not take into account some of the factors that may be obvious when one aims to design an interactive system for practical application. For instance, the embodied interactions used were very specific in their design, and the movements were large and were physically tasking. Therefore, for usability and ergonomic reasons, one could argue that this particular way of making this approach to interactive systems is not scalable to more practical domains. Therefore, we suggest that care must be taken when building further upon the way we have made our proof-of-concept interactive system.

Thus, the contribution of this study is a demonstration that an interactive system can be designed to use the function of motor expressions in emotion regulation to help people perform better on idea generation tasks that require creativity. We assume that our demonstration that the function of motor expressions in emotion regulation effectively influenced the emotion-creativity link, at least partly, positively answers *research question RQ1*.

The next step is to investigate the suggested limitations on the *effectiveness* of the approach developed in this study with regard to its ability to influence the emotion-creativity link. This however, will be the subject of future research, which will be addressed in more detail in the discussion chapter (section 8.5.1) of this thesis.

6. Study 3: Hacking into cognitive appraisal processes to augment creativity during idea generation

A paper that details the study discussed in this chapter was presented at the 2015 ACM SIGCHI Conference on Creativity and Cognition, June 2015, Glasgow, UK. This paper is included in Appendix E.

6.1 Introduction

In this chapter, we describe our second novel approach to interactive systems, which is designed to hack into the cognitive appraisal processes that form part of positive and negative emotions, with the goal to augment creativity during idea generation. In particular, this study focuses on explicating the mechanisms underlying the proposed approach. Based on experimental and theoretical findings from psychology (Baas et al., 2008; Roseman, 2011; Scherer, 2009), and the results from study 1 (chapter 4) and study 2 (chapter 5), we suggest that the degree to which one's own ideas are appraised as being original, causes positive or negative emotion, and that this can influence creativity during idea generation. On the basis of this argument, we developed for our final two studies, a proof-of-concept interactive system, which autonomously estimates the originality of the user's ideas, and presents these estimates as feedback to the user. This system is designed to be able to manipulate this feedback in a way that conveys that a user's ideas are less original, the same, or more original than people might typically expect, so that we are able to vary the likelihood that people appraise their own ideas as more or less original, and cause positive and negative emotion accordingly. Care is taken that this is done in a manner that is believable to users. The aim of the developed interactive system is to help explicate the mechanisms underlying the proposed approach in an experimental study. We hypothesize and experimentally demonstrate that the developed approach can be used to influence the way users appraise the originality of their own ideas, and that making the ideas look more original than they are causes more positive emotion, which augments creativity during idea generation. Thus, the contribution of the study presented in this chapter is a demonstration that an interactive system can be designed to use the function of cognitive appraisal processes in positive emotion, to help people perform better on idea generation tasks that require creativity (*research objective O3*). We assume that our positive demonstration, positively answers part of *research question RQ1*.

6.2 Causing emotion

Cognitive appraisal theory describes the way in which appraisals, or perceptions, of events in an individual's environment cause emotional responses (Moors, 2013; Roseman, 2011; Scherer, 2009). These appraisals typically feed forward to drive changes in other emotion components, which shape its adaptive response (Figure 15). That is, they determine for a large part the changes that an emotion brings about in the way people think and act. According to this theory, appraisals that indicate *goal-conduciveness* and *goal-obstruction*, differentiate positive from negative emotions. Goal-conduciveness and goal-obstruction refer to the way in which an event influences the progress toward attaining the individual's goals. That is, if the event implies that the current situation can lead to or led to attaining the individual's goals (e.g. good performance when the goal is to perform well), positive emotion is elicited, but when it implies the reverse (e.g. bad performance when the goal is to perform well), negative emotion is elicited. Other appraisals (e.g. of cause, coping potential, and norm violation) further differentiate the type emotion that unfolds (e.g. the difference between the positive emotions of joy and pride). See (Moors, 2013; Roseman, 2011; Scherer, 2009) for overviews.

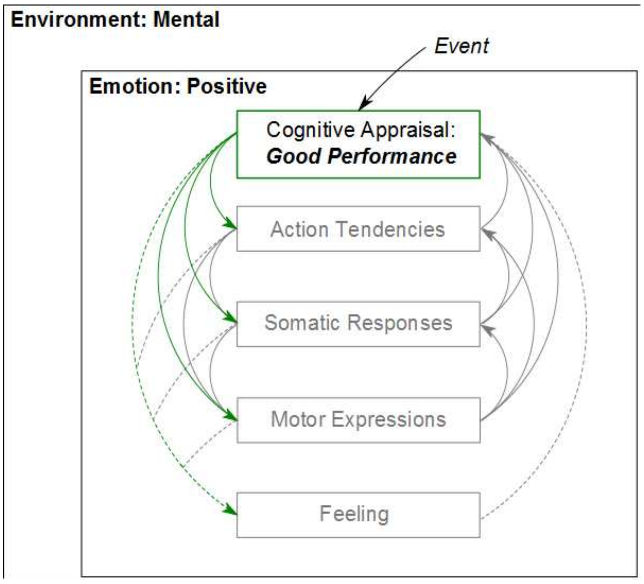

Figure 15 Schematic of the function of cognitive appraisal processes in emotion causation. An event in the environment causes emotion (e.g. a positive emotion), via cognitive appraisal processes (e.g.an appraisal of an event that is perceived as goal-conducive, such as good performance), by feeding forward to drive changes (green arrows) in the other emotion components.

There are, however, two *conditions* that need to be taken into account to enable these appraisals to lead to a sufficiently strong emotional response to impact the link between emotion and creativity during idea generation. We believe that both these two factors need to be taken into account when designing our interactive system.

First, certain *interactions between appraisals* can be conditional for an emotion to emerge (Brans & Verduyn, 2014; Sonnemans & Frijda, 1994). In addition to the influence of appraised goal-conduciveness or -obstructiveness on positive or negative emotion, the appraised *goal-relevance* of an event, i.e. the evaluation of how strongly the event affects the individual's current goals, moderates the degree to which other appraisal processes can cause an emotion (Kreibig et al., 2012; Nyer, 1997). For instance, when primed with achievement goals, performance feedback that is positive (success) and negative (failure) can elicit positive and negative emotions, but only when people appraise the performance feedback to be sufficiently relevant to their current goals (Kreibig et al., 2012). This suggests that an event should be perceived as both goal-relevant and goal-conducive to enable it to cause emotion. That is, without any goal-relevance an event is unlikely to cause an emotion that brings about noticeable change in the way people think and act.

Second, feedback connections among the emotion components (Figure 1), can create a temporary disposition to have the same emotion that was initially caused when they were first manipulated (Lewis, 2005; Scherer, 2009; Siemer, 2005). Thus, appraising an event in a particular way increases the likelihood that subsequent events will be appraised in a similar manner, because the changes that cognitive appraisal processes bring about in the other emotion components not only feed forward, but also feed back into these same emotion components (Siemer, 2005). It follows that when appraisals of a certain kind happen more closely together, this facilitates the emergence of the associated emotional response (Roseman, 2011). For instance, if there are only a few goal-conducive events over a period of time, one might feel slightly positive, but when something obstructive happens, one's emotional state might be prone to change. However, if the rate of goal-conducive events increases, positive emotion will emerge in a way that is more intense, and less prone to negative influences (Lewis, 2005; Roseman, 2011). Therefore, a certain *rate of goal-conducive events* is likely also to be necessary to cause a sufficiently strong emotional response for our approach to be effective.

It could be argued that *interactive systems* that are designed to hack into the cognitive appraisal processes that form part of emotions, exist implicitly in many different types of technologies. That is, it is unlikely that the use of emotion induction techniques from psychology (section 2.3.1.1), affective mirrors (section 2.3.1.3), and ways of mimicking social interactions (section 2.3.1.4) do not rely on some form of appraisal process to enable emotions to be caused. We believe, however, that our approach is closer to technologies that target reward and punishment, such as gaming technologies, which are conceptually closely related to the processes underlying appraisal theory (Koster, 2013). For instance, a popular approach to designing games is to set a minimal amount of points that need to be scored, as the goal that needs to be met to advance in the game. The accumulation of points scored throughout the game informs the appraisal of the progress of the player towards his or her goals, and causes positive emotion accordingly (Järvinen, 2007). Similar approaches have been taken outside the context of games, such as in the design of positive technologies (Calvo & Peters, 2014), persuasion, and generally technologies that aim to change behaviour (Eslambolchilar & Rogers, 2013). This indicates that interactive systems can be used to hack into the cognitive appraisal processes that form part of emotions. However, technologies that explicitly target appraisal processes with the goal to cause emotion, are relatively rare such as (cf. van Reekum et al., 2004). No interactive systems currently exist that explicitly attempt to *cause* emotion, rather than induce emotion in a more indirect manner (section 2.3.3.1), to influence the emotion-creativity link.

In this chapter we develop such a technology, by explicitly enabling an interactive system to manipulate the cognitive appraisal processes that cause and differentiate positive and negative emotions during idea generation.

6.3 Causing emotion to augment creativity

To develop a theoretical basis for an interactive system that can hack into the function of cognitive appraisal processes, to augment creativity, we attempt to bring together cognitive appraisal theory with the role of appraisals during idea generation (Figure 16).

Creativity during idea generation involves cycling back and forth through information processing steps that involve conceptual combination, the actual generation of ideas based different concepts, and the evaluation of these generated ideas (Lyer et al., 2009; Mumford et al., 2012). For instance, conceptual combination feeds forward into the idea generation step in the creative process to provide the concepts based on which ideas can be generated, whereas idea evaluation feeds back into the idea generation step in the creative process to provide information about the originality or usefulness of the generated ideas, which in turn shape the way people generate ideas (Lyer et al., 2009). Now, it is important to distinguish between the different ways in which idea evaluation is conceptualised. In this study, we treat idea evaluation as something that happens quickly and automatically, in a manner that forms part of the way people generate ideas, and in a manner that guides the generative process. Idea generation therefore always has a generative and evaluative component (Lyer et al., 2009). Note the idea evaluation as conceptualised in this study is different from the type of deliberate and reflective idea evaluation, which forms part of creativity techniques, and is often done to select ideas after for instance a brainstorm session (Isaksen et al., 2011). The focus on the former justifies use of the literature on the link between emotion and creativity during idea generation (section 2.2.1.1). Note that in our studies we refer to this particular cycle simply as *idea generation*, because we believe that we cannot isolate it from the conceptual combinations that feed forward, and the evaluations that feed back into the idea generation step in the creative process.

We assume that a cognitive appraisal theory of emotion (Roseman, 2011; Scherer, 2009), can also be applied to the appraisals that form part of the evaluation of ideas, and therefore idea generation (cf. Lyer et al., 2009). A technology that is designed to influence the appraisals that form part of positive and negative emotion, may therefore be able to help to intentionally cause positive and negative emotions during idea generation tasks.

Events that are *goal-relevant* within the context of idea generation, can be found by examining the function of idea generation in the creative process as a whole. Typically, the function of the generative component of idea generation is to output sufficient *original* material during the early stages of a creative process, whereas other goals, such as developing effective ideas, become more important during later stages (Cropley, 2006; Mumford et al., 2012). This is reflected in people's judgment of creativity, in which originality can weigh stronger than effectiveness for ideas developed in an idea generation task (cf. Forster & Dunbar, 2009). This indicates that within the context of idea generation, the appraised originality of an idea has at least some goal-relevance.

It follows from the above that generating original rather than unoriginal ideas is *goal-conducive* rather than *goal-obstructive*. We also found evidence for this in study 1 (chapter 4) and in study 2 (chapter 5). There, the amount of original ideas, and the percentage of ideas that are original, rather than for instance the total amount of ideas (fluency), have been shown to correlate positively with positive emotion during idea generation (Table 3, Table 5). This suggests that generating more original ideas associates with positive emotion, whereas generating more unoriginal ideas associates with negative emotion. We conjecture that an increase or decrease in *the rate of appraised original ideas* can thus drive a positive feedback loop between appraising originality, positive emotion, and generating originality, which enables the emergence of a sufficiently strong positive emotion to lift both emotion and creativity simultaneously, and robustly. Note that this is different from study 2 (chapter 5), where we assumed, based on empirical results by others (Akhbari Chermahini & Hommel, 2012a; Brunyé et al., 2013; Zenasni & Lubart, 2011), that positive emotions were caused by the generation of many and diverse ideas. An interactive system that targets the rate at which original and unoriginal ideas are produced can therefore be assumed to target the link between positive emotion and creativity during idea generation. In this study we develop and investigate such an interactive system.

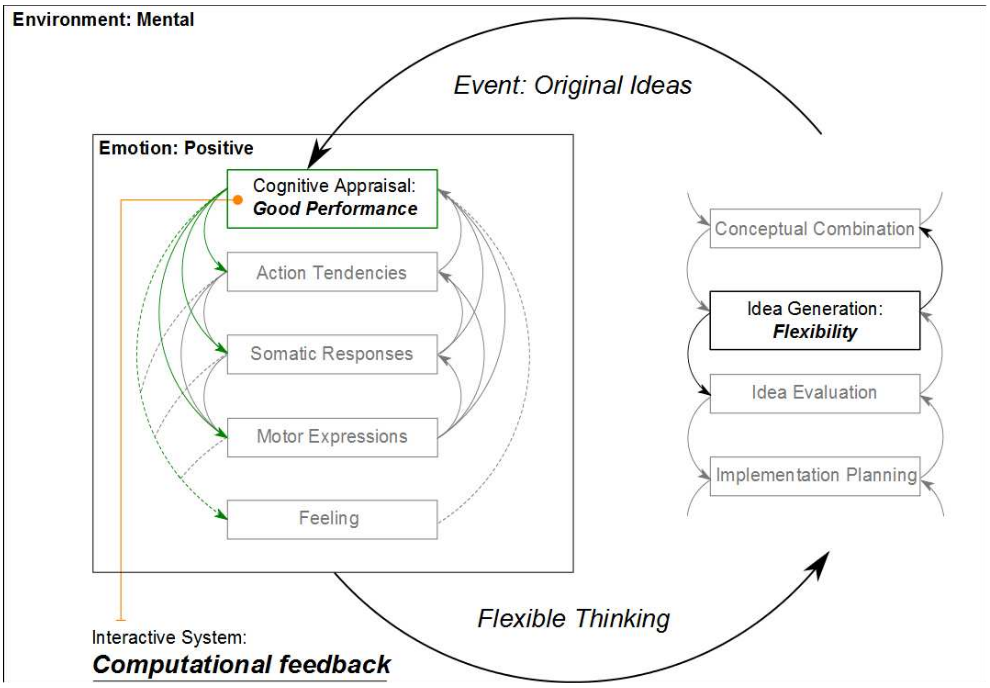

Figure 16 A schematic of our use of cognitive appraisal processes to influence the emotion-creativity link. The figure shows the function of cognitive appraisal processes in causing positive emotion (left, green arrows), the influence of positive emotion on creativity during idea generation (right), and the way the interactive system makes use of this relationship to influence the emotion-creativity link (bottom-left). Note that the event that causes positive emotion is now assumed to be the generation of original ideas.

In section 2.3.3.2 we discussed possible limitations of interactive systems that are designed to influence the emotion-creativity link. The gist of this discussion was that in order to be effective, the way such an interactive system influences emotion should be meaningful within the context of a creative task. In study 1 (chapter 4) and study 2 (chapter 5) we developed a novel approach to interactive systems that addresses these issues by making use of the function of motor expressions in emotion regulation. We believe that using *interactive systems* to influence the cognitive appraisal processes that cause emotion during a creative task, is another (cf. section 5.3), second approach that can tackle these limitations by providing meaningful interventions. This is, as we have discussed above, because the cognitive appraisal processes that help cause emotion during a creative task, are specific to the goals people have during that creative task. If such an interactive system can provide information or feedback that is believable enough so that people take this feedback into account during their appraisal processes, then the interactive system can influence emotion in a manner that is meaningful to a creative task. For this reason, we believe that hacking into cognitive appraisal processes may be an effective approach to interactive systems that attempt to influence the emotion-creativity link.

To further develop and investigate this, until now, theoretical conjecture, we will focus on targeting appraisals about originality to hack into the cognitive appraisal processes that cause positive and negative emotion during idea generation.

6.4 Interactive system

To evaluate our conjectures, we have developed a proof-of-concept interactive system that is designed to influence the appraisal processes underlying positive and negative emotion during idea generation. First, the system is capable of estimating the originality of an idea in a believable, human-like way, in real-time. Second, the system is designed to manipulate feedback on the originality of an idea in such a way that the user's ideas appear less, the same, or more original than they really are. Finally, the system enables textual input of ideas, and presents the manipulated feedback on those ideas after typing, so that this can help the user to appraise his or her own ideas, with the aim of influencing the user's appraisals of their ideas and thereby increasing their creativity.

6.4.1 Estimation of originality

We operationalize originality as the statistical infrequency of an idea (Guilford, 1967; Plucker et al., 2011). This is the same definition used in our previous studies when using the objective scoring method to assess creativity (section 3.3.2). It follows that the frequency of an idea in a large collection of ideas about a particular subject might indicate the originality of that idea. Calculating originality thus requires a way of 1) representing ideas, 2) representing the space of ideas about a particular subject, and 3) using that idea space to estimate the originality of a new idea. See (Forster & Dunbar, 2009; Harbison & Haarmann, 2014) for related approaches.

6.4.1.1 Idea representation

In our system, an idea is represented as an unstructured collection (set) of word senses and related concepts. To generate this representation, the system takes an idea in natural language, disambiguates the part-of-speech of the words in the ideas using the Hun-pos tagger, as developed by (Halácsy et al., 2007), extracts the verbs and nouns, and then disambiguates the word sense of these verbs and nouns using the Adapted Lesk algorithm, as developed by (Banerjee & Pedersen, 2002). We assume that most of an idea's meaning is contained in the verbs and nouns in that idea. To make this approach less sensitive to different ways of phrasing the same idea, the IS-A (e.g. a house is a building) and PART-OF (e.g. a room is part of a house) relations of the extracted senses are retrieved from WordNet (Fellbaum, 1998) to form a concept network for each idea.

6.4.1.2 Idea space generation

To be able to estimate the originality of an idea the system requires an idea space. This is created by taking a large collection of ideas, extracting the word senses from these ideas as previously described, and storing and counting the frequency of all these word senses. For this study we used the ideas that had been generated in previous studies using the same idea generation task that we will use in this study (i.e. the AUT). These were taken from study 2 (chapter 5) and from studies by (Griffin & Jacob, 2013; Silvia et al., 2008; Slepian & Ambady, 2008) (Table 8), which were kindly donated by the respective authors of the papers of those studies. This enabled us to generate three idea spaces, representing ideas about using a brick, a paperclip, and a knife. This was technically feasible, because the collections of ideas that were used, were already constrained to the AUT subjects.

Subject	n-people	n-ideas	Taken from
Brick	409	3504	Study 2; Griffin & Jacob, 2013; Silvia et al., 2008; Slepian & Ambady, 2012.
Paperclip	210	2128	Griffin & Jacob, 2013.
Knife	242	1698	Silvia et al., 2008.

Table 8 Characteristics of the idea collections.

6.4.1.3 Estimation of originality

To estimate the originality of a new idea the system extracts the concepts from this idea and retrieves the frequencies of these concepts from the idea space representation. For each idea the system summarizes the frequencies of the extracted concepts, or senses (including the associated senses) by computing the grand mean. That is, the mean of the means for each of the senses and their associated concept networks. This is done to insure that the contribution of each sense is not strongly dependent on the amount of semantically related senses found in WordNet, and to reduce the dependency of the scores on the amount of verbs and nouns that are present in an idea. The system then computes the percentile rank of the grand mean relative to the grand means of all the ideas used to generate the idea space for a particular subject. This yields a ranked originality estimate that ranges between 0 (=very unoriginal) to 100 (=very original). This is the system's estimate of originality that is used in the study.

6.4.1.4 Pre-study: Human-likeness of the systems estimates

To investigate whether the system's estimates corresponded with human estimates we asked people to estimate the originality of 45 ideas (15 for each subject in Table 8). We asked people to use a Likert scale from 0 to 10 (0=very unoriginal, 10=very original) to 1) estimate how original they thought each idea was, and 2) state what was the lowest and the highest score that they felt could reasonably be given for each idea. Thirty-one people (16 females, 15 males, M_{age}=34.6, SD_{age}=9.87) rated the ideas in this way. These people were students and employees of a UK and a Dutch university, and did not participate in the main experiment. The same set of ideas was also rated by the developed system.

To test the consistency of the human ratings of originality and compare these with the system's ratings we first calculated the mean correlations between the participants' ratings (averaged using Fisher's z-transform). The results showed that the originality estimates by the participants correlated on average weakly to moderately to each other, $.260 < \bar{r} < .673$, with

$\bar{r}$=.526. The mean correlation between the system's estimates and the estimates of the participants was similar, $\bar{r}$=.453. This indicates that people rate the originality of ideas in a manner that has limited consistency, and that the consistency of the ratings of originality by the system with those of the participants, is similar to the consistency observed among the participants. This supports our assumption that a collection of ideas about one subject can be used to estimate the originality of an idea in a manner that is consistent with human estimates.

6.4.2 Feedback manipulation

For our experimental purposes we enable the system to manipulate the feedback it provides on ideas so that it seems to users that their ideas are 1) less original than they might expect (*negative*), 2) similar to what they expect (*neutral*), or 3) more original than they expect (*positive*). To make sure that these *feedback manipulations* are believable (e.g. not too positive that the user would not take the feedback seriously anymore), we used the data from the pre-study described above to fit three mapping functions (Table 9) that could map the originality of an idea as calculated by the system to a believable rating for use in the positive, neutral or negative conditions, as described below.

All the functions were generated using curve fitting. These curves were fitted without an intercept to force the polynomial to pass through zero. For the neutral manipulation we fitted the systems unmanipulated estimates, with the human estimates. The resulting mathematical function maps the system's unmanipulated estimates to approximate to the originality appraisals that people usually expect. To obtain the negative and positive mappings we fitted the human estimates with the lowest and highest scores the participants felt could reasonably be given, using a quadratic function.

The resulting functions map the estimates that are processed by the neutral mapping, to originality estimates that are worse or better than people typically expect.

Feedback manipulation	Mapping function
Negative	$f(x) = .441x + .004x^2$
Neutral	$f(x) = .814x$
Positive	$f(x) = 1.794x - .008x^2$

Table 9 Generated mapping functions for the negative, neutral, and positive feedback manipulations.

We assume that if users believe the feedback to provide information that is relevant for the appraisal of their own creative task performance, then these manipulations should influence the way emotions are caused, and thereby influence the link between emotion and creativity.

6.4.3 Presenting the feedback

To enable basic textual input of ideas and effectively communicate the feedback on those ideas we developed a user interface. Users can type in their ideas in text blocks using the English language. Upon pressing ENTER the system estimates the originality of an idea, and maps this score to an output value using the pre-specified negative, neutral, or positive feedback manipulation. The resulting output is presented as informational feedback about the idea the user just generated (Figure 17). The feedback is presented by using a colour code (red=unoriginal, orange=somewhat unoriginal, amber=somewhat original, green=original), and numerically using the manipulated ranked estimate of originality.

We assume that presenting the feedback right after each idea is generated, collides with the moment that the user will anyway tend to evaluate his or her idea, so that the system can inform the user's appraisals of the originality of his or her own ideas, which may then target the hypothesized link between positive emotion and creativity during idea generation.

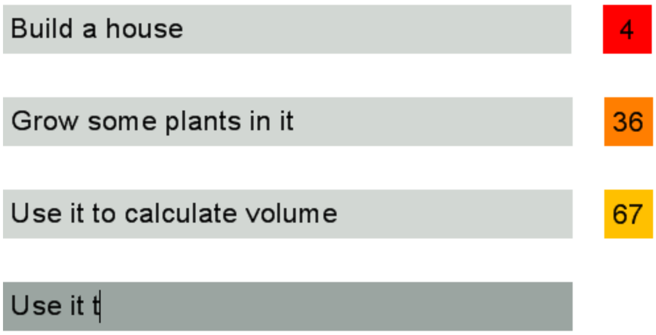

Figure 17 A screenshot of the way feedback is presented showing text entry (left), and feedback (right). The ideas and feedback shown here are responses to the brick as a subject, with the negative feedback manipulation.

6.4.4 Hypotheses

To put our theoretical conjectures and developed proof-of-concept interactive system to the test, we experimentally test the following five hypotheses (Table 10).

#	Hypothesis
H1	*Positive, rather than negative emotion associates with augmented creativity.*
H2	*Positive, rather than neutral or negative manipulation of feedback presented by the interactive system augments creativity.*
H3	*Positive, rather than neutral or negative manipulation of feedback presented by the interactive system causes positive emotion.*
H4	*Negative, rather than neutral or positive manipulation of feedback presented by the interactive system causes negative emotion.*
H5	*Positive, rather than neutral or negative manipulation of feedback presented by the interactive system augments creativity via its influence on the emotion-creativity link.*

Table 10 Hypotheses for study 3.

6.5 Method

To test the hypotheses and thereby experimentally evaluate the interactive system, we used an experimental within-subject design, with each of the participants doing three creative tasks while being exposed the *negative, neutral, and positive* feedback manipulations described above. The feedback manipulations and the objects used in the creative tasks were randomized to prevent research bias.

6.5.1 Participants

In total, 49 people (25 women, 24 men, M_{age}=30, SD_{age}=8.38) participated in our study. Two participants guessed the purpose of the study and five people reported to have tried to game the interactive system by typing in bizarre ideas to gain high originality scores during one or more of the tasks. We removed these cases from further analysis to ensure that the possible extraneous sources of variation they introduce did not influence testing the hypotheses, and thereby threaten the internal validity of the study. This resulted in 134 usable cases. All participants were students or employees of City University London.

6.5.2 Materials and measurements

6.5.2.1 Creative tasks

To gather data based on which we could assess the participant's creative capabilities during idea generation, we again used the AUT (section 3.3.1). Participants were instructed to "*…come up with as many, diverse, and original uses for the common object as you can*", within 4 minutes. See section 4.5.2.1 for the rationale underlying these particular instructions. Participants used the interactive system to do the AUT three times, with the brick, paperclip, and knife as a subject. That is, the AUT subjects about which the interactive system is able to estimate the originality of people's ideas (Table 8). Presentation order was randomized. Note that the AUTs results are susceptible to learning effects, which can introduce an extraneous source of variation in the data (section 3.3.1). This is introduced by the use of a within-subject design. Although randomization might mitigate learning effects to some degree, it is unclear to what extent this occurs. Therefore, we need to accept this threat to validity.

6.5.2.2 Assessment of creativity

We used the system's *originality* estimates to assess creativity (cf. section 3.3.2). Any idea scoring above the 75th rank, according to the unmanipulated estimate calculated by the system, was counted as an original idea (26% of the ideas in this study). For each participant, we again used the percentage scoring method. That is, we divided the number of original ideas by the total number of ideas generated during a task. See section 5.5.2.2 for the rationale underlying this correction. Note that use of the system's originality estimate might introduce measurement error. Despite the results of our pre-study, which show that the system estimates originality with a similar consistency as humans do, we do not know whether the systems estimates agree or disagree in the same way people agree or disagree, which could threaten construct validity. However, since the feedback that is used to influence the participant's emotions is based on this automated originality score, not using it would threaten the study's internal validity. We chose to support the latter.

6.5.2.3 Assessment of emotion

The participants used Likert scales with emotion words on opposite ends to self-report feelings of satisfaction (1=not satisfied, 9=very satisfied) and frustration (1=not frustrated, 9=very frustrated) they had experienced during the task (section 3.3.3). We assumed that these emotion words would reflect the type of negative and positive emotions typically associated with goal-conduciveness and goal-obstruction while pursuing a goal under time pressure in this way (cf. Roseman, 2011; Scherer, 2009). We assumed that this would make it easier for participants to recall their feelings after the tasks, and therefore help reduce measurement error. We also assessed positive and negative feelings separately, instead of as opposites on one scale, which we did in study 1 (section 4.5.2.3) and study 2 (section 5.5.2.3). This was changed because this allowed us to test the effects of positive and negative emotion on creativity separately, which better reflects empirical findings that show that positive emotion influences creativity (section 2.2.1.1), but negative emotion does not necessarily have any influence on creativity, or has a diminishing influence on creativity, during idea generation (section 2.2.1.2). Further potential sources of measurement error were addressed in the way described previously in section 4.5.2.3.

6.5.2.4 Manipulation checks

Several checks were carried out to support the internal validity of the study design (section 3.3.4). It is conceivable that the feedback manipulations could have made the system's estimates less believable, rather than having the intended effects. To check whether the feedback manipulations in fact led to the intended influences on appraised originality of ideas, the participants used a Likert scale to rate their own creative performance after each task (1=worse, 9=better than expected), as well as how reliable the participants thought that the feedback was (1=very unreliable, 9=very reliable).

6.5.3 Procedure

Upon arrival the participants were seated at the computer and introduced to the study and its procedure. We used a cover story that informed the participants that we were testing *"... the efficacy of using computer supported idea evaluation,"* but withheld information about the actual experimental conditions until the end of the experiment. Informed consent was signed, and the participants filled in a brief questionnaire to collect personal data (age, gender). We then provided instructions for the tasks. That is, that the participants would do three AUTs during which our interactive system would provide feedback about the originality of each idea they came up with, provided further instructions needed to do the AUT, and emphasised that their goal was to "*…come up with as many, diverse, and original uses for the common object as you can*" during each task. For the system's feedback we emphasized that participants should *"… use the feedback as a guide that helps you during your idea generation process."* A picture of the common object used during each AUT was shown just before each task to inform the participant's about the type of alternative uses they were supposed to generate. After this participants did the AUT. That is, participants would type in their ideas, and during which they received manipulated feedback about the originality of their ideas each time they typed in an idea and pressed ENTER. Thus, attempting to manipulate their appraisal processes and subsequent emotional responses. Each task took exactly 4 minutes. These 4 minutes were timed internally by the interactive system, after which the system prevented the participant to typing in further ideas. The common objects used, and the feedback manipulations were randomised automatically by the interactive system. Right after each task ended the interactive system prompted a request to the participants to fill in a questionnaire. This questionnaire contained the measurement instruments used to assess emotion and carry out the manipulation checks. Throughout the tasks, the interactive system automatically logged the actual unmanipulated originality scores it computed for each idea, which were used to assess creativity. After the three tasks and questionnaires were finished the participants were debriefed. During this debrief the true purpose of the study was explained, and we asked the participants whether they had guessed this purpose, had tried to game the feedback by typing in bizarre ideas, or had problems using the system otherwise. To compensate the participants for their effort, we handed them a £5 voucher for a large online retailer, and a chocolate bar. A graphic representation of the procedure is presented in Figure 18.

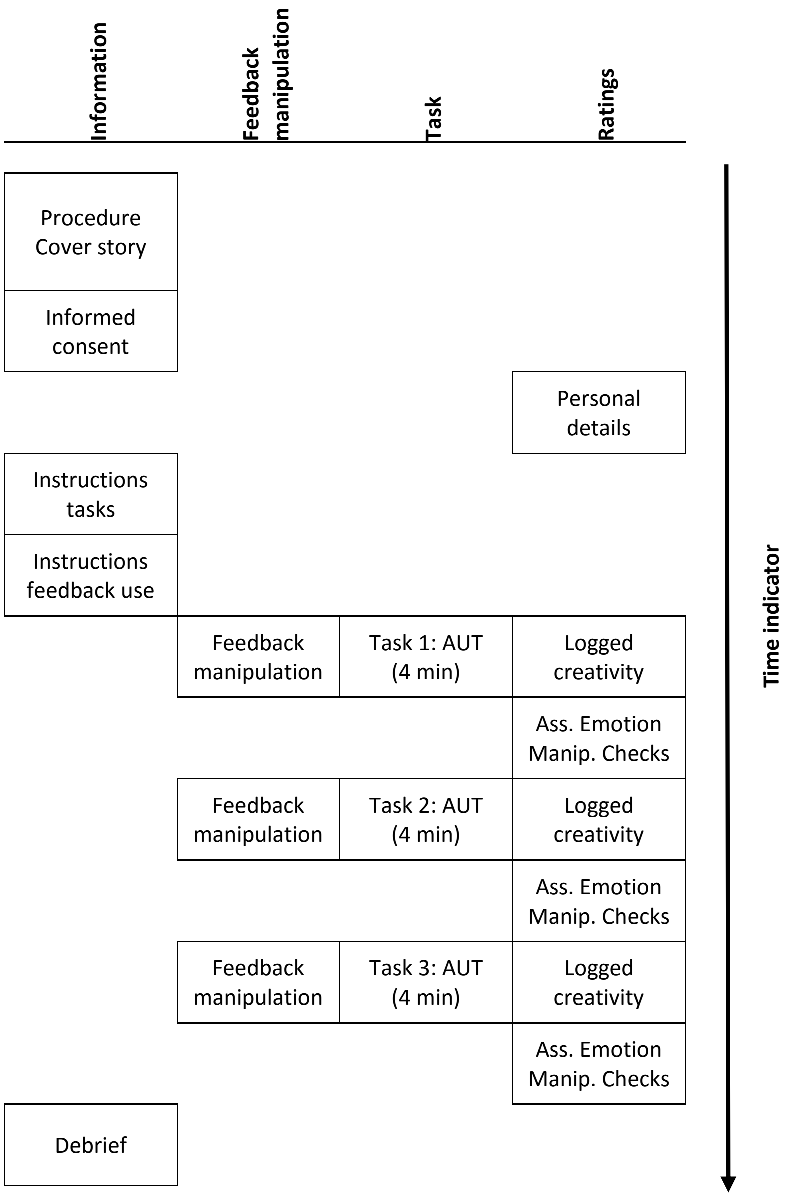

Figure 18 Graphic representation of the order and timing of information, when the feedback manipulations were used to influence the appraisals of the user's own ideas, the tasks performed, and the ratings used in the procedure.

6.5.4 Analysis

To analyse the data from our study, we used linear mixed model (LMM) analysis with two levels (Field, 2013). The feedback manipulations were entered as the repeated measures fixed effects at level-1, with random intercepts for the participants nested at level-2. This enabled analysis on repeated measures with missing cases (Field, 2013), such as the one's we removed from the collected data (section 6.5.1). This is not possible with, for instance, repeated measures ANOVA, which is a more common quantitative technique to analyse repeated measures data (Field, 2013). To obtain a suitable covariance structure for the LMMs we entered the data with different covariance structures and minimized the -2 Log likelihood (-2LL) and the model's degrees of freedom. We only accepted models with more degrees of freedom when the decrease in -2LL significantly differed from a simpler model given the χ^2 distribution (Field, 2013). For each of the DVs we arrived at the scaled identity covariance structure as the best fit, which is used to report our results in the following section.

6.6 Results

We first did two manipulation checks to test whether the feedback manipulations targeted the way participants appraised the originality of their ideas as intended, by submitting the manipulation checks individually as DVs to an LMM, with the feedback manipulations as the IV. The results suggested that there was a significant effect of the feedback manipulations on perceived creative task performance, $F(2, 87.86)=55.19$, $p<.001$. Complementarily, the results suggested that there was no significant effect of the feedback manipulations on the perceived reliability of the feedback, $F(2, 87.91)=.554$, $p=.577$. This indicated that the feedback manipulations had the intended effect.

To test whether there was an association between emotion and creativity across the experimental conditions, we correlated originality, with satisfaction (positive emotion) and frustration (negative emotion) (Table 11). Because the data were repeated measures, person-mean centering was used to remove between-person variance (Enders & Tofighi, 2007). The results suggested that there was a significant positive correlation between satisfaction and originality, and a significant negative correlation between frustration and originality. These findings indicate that positive, rather than negative emotion associates with increased creativity during idea generation, which indicates that there is a relationship between emotion and creativity in the data. This supports hypothesis H1.

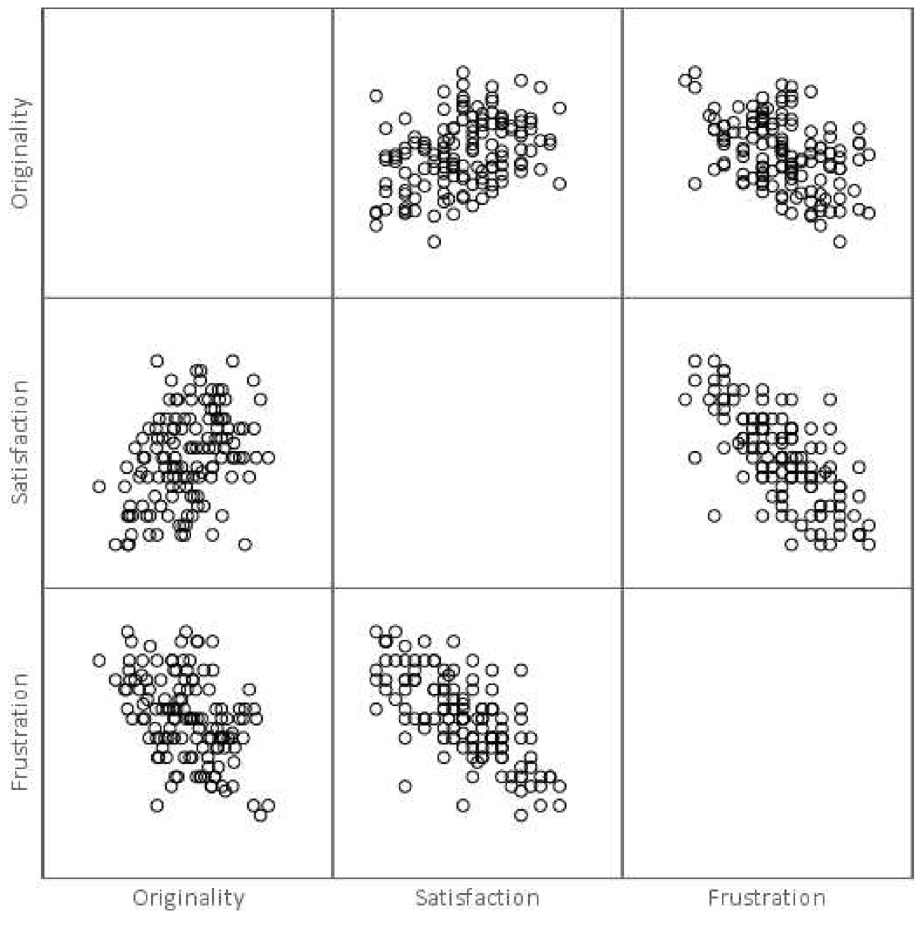

Figure 19 Scatterplot matrix of the dependent variables originality, satisfaction, and frustration. These variables were person-mean centered

DV	1.	2.	3.
1. Originality	-		
2. Satisfaction	.382**	-	
3. Frustration	-.438**	-.733**	-

*Table 11 Pearson correlation coefficients for originality, satisfaction, and frustration (DVs). These variables were person-mean centered. *p<.05, **p<.001.*

IV	Originality	Satisfaction	Frustration
Negative	.225 (.142)	3.42 (1.71)	5.87 (1.70)
Neutral	.254 (.119)	4.80 (1.70)	5.13 (1.77)
Positive	.292 (.145)	6.14 (1.50)	3.80 (1.89)

Table 12 Means and standard deviations (between parentheses) of originality, satisfaction, and frustration (DVs) for the negative, neutral, and positive feedback manipulations (IV).

IV	Originality	Satisfaction	Frustration
Negative	-.067* (.026) [-.120 -.015]	-2.70** (.29) [-3.28 -2.11]	2.07** (.31) [1.46 2.67]
Neutral	-.036 (.026) [-.088 .016]	-1.32** (.29) [-1.90 -.73]	1.33** (.31) [.72 1.93]
Positive	.[a]	.	.
Intercept	*.292* (.021) [.249 .334]*	*6.12** (.24) [5.65 6.61]*	*3.81** (.27) [3.29 4.34]*

*Table 13 Estimates of fixed effects of the feedback manipulations on satisfaction, frustration, and originality. Unstandardized estimates, standard errors (between parentheses), 95% confidence intervals (between square brackets). *p<.05, **p<.001. [a]Data relative to the positive condition, as modelled by the intercept.*

To test whether there was an effect of the way the interactive system was used, on positive emotion, negative emotion, and on creativity individually, we submitted satisfaction, frustration, and originality individually as DVs to an LMM, with the feedback manipulations as the IV. The descriptive statistics are presented in Table 12, a scatterplot matrix of the dependent variables is presented in Figure 19.

Estimates of fixed effects suggested that there was a significant effect of the feedback manipulations on originality, $F(2, 89.74)=3.33$, $p=.040$. Compared to the positive condition (which corresponds to the intercept shown in Table 13), participants were less likely to generate original ideas in the neutral condition (albeit not significant), and even less likely to generate original ideas in the negative condition. Note however, that despite this trend, only the difference between the negative and the positive conditions was significant. These findings indicate that positive, rather than neutral or negative manipulation of feedback presented by the interactive system augments creativity. This supports hypothesis H2.

Estimates of fixed effects also suggested that there was a significant effect of the feedback manipulations on satisfaction, $F(2, 89.86)=42.27$, $p<.001$. Compared to the positive condition, participants reported significantly less satisfaction in the neutral condition, and even less satisfaction in the negative condition. The findings indicate that positive, rather than neutral or negative manipulation of feedback presented by the interactive system causes positive emotion. This supports hypothesis H3.

Finally, estimates of fixed effects suggested that there was a significant effect of the feedback manipulations on frustration, $F(2, 89.94)=23.55$, $p<.001$. Compared to the positive condition, participants reported significantly more frustration in the neutral condition, and even more frustration in the negative condition. The findings indicate that negative, rather than neutral or positive manipulation of feedback presented by the interactive system causes negative emotion. This supports hypothesis H4.

Because the results from the LMMs indicated that there was an effect of the feedback manipulations on satisfaction, frustration, and originality independently, but the correlations also indicated that there was a positive relationship between satisfaction and originality, and a negative relationship between frustration and originality across the experimental conditions, we assume that the interactive system developed for this study can influence the emotion-creativity link effectively. Therefore, the results also support hypothesis H5.

In terms of model quality the estimates of covariance showed that the feedback manipulations (repeated measures, Table 14) represented the majority of variability in these models. However, in all cases the variance for the random intercepts (participants) was significant as well (intercept, Table 14), which shows that there were variables that could explain differences between the individuals in the relationship between the feedback manipulation, and originality, satisfaction, and frustration, that we did not measure.

	Originality	**Satisfaction**	**Frustration**
Repeated measures	.015** (.002) [.011 .020]	1.90** (.29) [1.41 2.55]	2.05** (.31) [1.53 2.75]
Intercept (subjects)	.005* (.002) [.002 .012]	.73* (.30) [.33 1.65]	1.06* (.38) [.52 2.13]

*Table 14 Estimates of covariance for the LMMs for the DVs originality, satisfaction, and frustration. Unstandardized estimates, standard errors (between parentheses), 95% confidence intervals (between square brackets). *p<.05, **p<.001.*

6.7 Discussion

Our findings demonstrate that an interactive system can be designed to hack into the function of cognitive appraisal processes in emotion, positive emotions in particular, and that this can be used to augment creativity during idea generation (*research objective O3*).

The findings suggest that positive (satisfaction), rather than negative emotion (frustration) associates with augmented creativity during idea generation (H1). This indicates that there was a relationship between emotion and creativity that the interactive system could influence. The findings also suggest that positive, rather than neutral or negative manipulation of computational feedback, augments creativity during idea generation (H2). This indicates that the positive manipulation of the appraisal of how original a user's own ideas are, by our interactive system, influences the likelihood that subsequently generated ideas will also be original. Furthermore, the results suggest that positive, rather than neutral or negative manipulation of computational feedback causes positive emotion (H3); and that negative, rather than neutral or positive manipulation of computational feedback causes negative emotion (H4). This suggests that the positive and negative manipulation of the appraisal of how original a user's own ideas are, by our interactive system, influences positive and negative emotion respectively. Therefore, we assume that the results also suggested that positive, rather than neutral, or negative manipulation of the feedback provided by our interactive system augments creativity via its influence on the emotion-creativity link (H5). That is, the effects of the interactive system on positive (H3) and negative (H4) emotion, and on creativity (H2), can be explained by the effects of the system on the emotion-creativity link (H1).

There were however also limitations to this study that relate to the use of control groups. Although we consider the neutral feedback manipulation to be a control group, that is, an experimental condition that is meant to function as a reference to which we can compare the positive and negative feedback manipulations, we did not control for not using feedback at all. Several implications arise from the lack of such a control condition that delimit the conclusions drawn from this study.

In particular, the use of a non-feedback control group may have had a direct influence on the emotion-creativity link. It is conceivable that neutral feedback manipulation would not have resulted in similar ratings of emotion because receiving feedback in itself can for some people associate with negativity or positivity. For instance, it may be that some participants associate feedback with authority, which threatens their autonomy and thereby influences emotions, and possibly the emotion-creativity link accordingly (Bujacz et al., 2015). Speculatively, such effects might apply more strongly to receiving negative feedback, and possibly less strong for neutral or positive feedback (cf. Shepperd et al., 2008), which would indicate a more complicated relationship between feedback, feedback manipulation, and the emotion-creativity link than was developed in this study. It is clear that since we did not include such a control group, inferences of this kind cannot be made on the basis of the study's results. However, this does point to an interesting novel direction for future work, one that is more sensitive to individual differences and context in which the developed approach to interactive systems is used.

In addition, the inclusion of an experimental condition where no feedback was used could have gained insight into whether receiving feedback in itself is either detrimental, conducive, or has no effect on creativity when compared to not receiving feedback. A study that includes such a control condition can help justify the use of feedback and feedback manipulation as an approach to interactive systems that influence creativity by manipulating the appraisal processes that form part of positive and negative emotions during idea generation. For instance, and similar to the discussions of control groups in study 1 (section 4.7) and study 2 (section 5.7), it might be that the need to process the system's feedback burdens working memory in a manner that hampers creative thinking (cf. de Dreu et al., 2012). Alternatively, one could argue that the feedback provided by the interactive system makes it in fact easier to do a creative task. That is, the system takes over the appraisal part of the idea generation process and therefore the user does not have to sacrifice working memory capacity to these appraisals, but can rather direct these resources to the generate part of idea generation. However, it might as well be that these cancel each other. In any case, we cannot draw conclusions of this particular kind, but it would be worthwhile to design a further study that investigates this.

We would also like to point out that it could be worthwhile to focus future studies on individual differences as well. First, recent studies suggest that people may strongly differ in the way they mobilise the emotional, motivational, and cognitive changes necessary to perform well on a creative task (Soroa et al., 2015). For instance, people differ in the degree to which they get motivated to do a creative task, the degree to which they experience positive emotions in response to a creative task, and in the type of approach to creative problem solving they prefer to use (e.g. by generating many, diverse ideas, or by exploring only a few ideas in depth (cf. Baas et al., 2008; Soroa et al., 2015)). This particular line of work ties in with research on how people respond to feedback. Reward sensitivity theory suggests that there are individual differences in sensitivity to reward, punishment, and motivation (Corr, 2008). It is likely that reward and punishment sensitivity interact with, or are even at the basis of differences in the way people mobilise the emotional, motivational, and cognitive changes necessary to perform well on a creative task (cf. Baas et al., 2008; Soroa et al., 2015). This further points toward the complexity of using feedback manipulation as a means to target the emotion-creativity link. Future work should therefore include individual difference measures that take into account reward sensitivity (Carver & White, 1994) and individual differences in how people mobilise their emotional, motivational, and cognitive resources during different creative tasks (Soroa et al., 2015).

In addition, it is necessary to point out that our decision to measure positive and negative emotion as satisfaction and frustration may have introduced confounding factors into our assessment of the effects of our interactive system on the emotion-creativity link. That is, we know from the literature review on the emotion-creativity link (section 2.2) that different aspects of a positive or negative emotion can influence creativity in different ways. It may therefore be that there were also differences in for instance arousal (section 2.2.2.1) or motivational direction (sections 2.2.2.2 and 2.2.2.3) that could (also) explain (part of) the effects of the interactive system on the emotion creativity link. These however, we did not measure. So any confounding factors cannot be ruled out.

There were also some inconsistencies in the data that might point to limitations in the *effectiveness* of our second approach to interactive systems that are inherent to the way it was made. Although the impact of our system on positive and negative emotion appeared to be effective, not all results for originality differed significantly. Although there is a clear trend that matches our hypotheses, the standard deviations and confidence intervals show that there is also a clear overlap between the conditions, and as a result no significant difference was found between the positive and neutral feedback manipulations. On the one hand we can argue that using the system's estimates of originality as a measure introduces unnecessary noise into the data, which makes the rejection of the null hypothesis less likely and therefore increases the chance of a type II error. This is to be expected due to the limited consistency with which people, and in the same way, the interactive system, estimate originality. On the other hand, this overlap is likely to be inherent in the way the interactive system is designed to manipulate the feedback. That is, the feedback the user receives depends on the user's own ideas, and can be manipulated only so much without jeopardizing its believability. It is, therefore, likely that the system could in some cases not increase the feedback enough to increase the rate of goal-conducive events to generate a sufficiently strong positive emotion.

The results point toward a limitation in the way our second approach to interactive systems was conceived and as such questions the assumptions that went into its development. With our experimental setup it is not possible to prove that there is a reciprocal relation between the appraised originality of someone's ideas, positive emotion, and the actual generation of original ideas, which was assumed when conceiving our approach. This leaves the experimental study open for alternative interpretations, and thereby threatens the studies' internal validity. For instance, it could be that more negative feedback is simply more inhibiting than positive feedback. Many creativity techniques emphasize that less inhibition (e.g. deferring judgment) is key to creativity (cf. Cropley, 2006; Mumford et al., 2012). It is conceivable that people experience positive and negative emotion accordingly, without any impact on a reciprocal link between emotion and creativity. However, theory, and our own findings about the causal relation between the feedback, positive emotion, and originality are in fact more in line with our own explanation.

It is also worth noting that the use of a within-subject design poses a particular threat to the construct validity of AUTs used in this study (Shadish et al., 2002). First, the used AUT is sensitive to learning effects, which are likely to have occurred over the three AUTs, which were administered one after the other. Second, ideas generated during previous AUTs might have inspired ideas in subsequent AUTs, which might have influenced the originality of the user's ideas, and therefore introduced an extraneous source of variation into the data. Third, doing the AUT three times may have led participants to get bored or fatigued during the tasks, which would have also introduced an extraneous source of variation. This introduces several ways in which the use of a within-subject design can threaten the construct validity of the used AUTs. The advantage, however, of the within-subject design is increased statistical power. This helped us to deal with issues in our previous studies, where we had to work with sample sizes that were on the low side (sections 4.7, 5.7).

Furthermore, we believe it is good to mention again that we developed the proof-of-concept interactive system specifically to test our hypotheses (section 3.2.2). As a consequence of that decision, we did not take into account some of the factors that may be obvious when one aims to design an interactive system for practical application. In particular, the use of ideas generated during previous AUTs, as a basis for the system to estimate originality, constrains the semantics of these ideas to the subject used in the AUT. That is, we already know that the ideas in the dataset are about the AUT's subject (e.g. uses of a brick). This is convenient because it circumvents a bottleneck in natural language processing technology, which is the difficulty of current information technologies to relate random ideas (sentences) semantically to each other in an accurate way (Cambria & White, 2014). The existence of this technological bottleneck might limit the degree to which the way we made this particular interactive system can scale from the AUTs to real-world creativity. Therefore, we suggest that care must be taken when building on the particular way that we have made our proof-of-concept interactive system.

Thus, the contribution of the study presented in this chapter is a demonstration that an interactive system can be designed to use the function of cognitive appraisal processes in positive emotion, to help people perform better on idea generation tasks that require creativity. We assume that our demonstration that the cognitive appraisal processes that form part of positive and negative emotion during idea generation, can be used to effectively influence the emotion-creativity link, positively answers part of *research question RQ2*.

The next step is to investigate whether the mechanisms underlying the proposed approach to interactive systems developed in this study can be built upon to make use of other functions of cognitive appraisal processes in emotion. In particular, we are interested to find out more about whether the developed approach to interactive systems can also be used to help *determine emotional intensity*. The ability of an interactive system to help determine emotional intensity might be of particular interest because it might enable such a system to help determine the degree to which an interactive system influences the emotion-creativity link (cf. sections 2.2.1.1, 2.2.1.2). This will be explored in study 4 (chapter 7).

7. Study 4: Hacking into cognitive appraisal processes to determine emotional intensity to augment creativity during idea generation

7.1 Introduction

In this chapter, we describe the reconfiguration of the approach to interactive systems developed in study 3 (chapter 6), with the aim to investigate whether this approach can also effectively hack into the function of cognitive appraisal processes in determining emotional intensity. In particular, this study focuses on explicating the mechanisms underlying the proposed reconfiguration. Based on experimental and theoretical findings from psychology (Brans & Verduyn, 2014; Carver & Scheier, 1990; 1998), we conjecture that the cognitive appraisal processes that cause positive and negative emotions also condition the expectations people have about similar, subsequent, events. In turn, these expectations provide a frame of reference against which these appraisal processes determine emotional intensity. The ability of an interactive system to help determine emotional intensity may enable such a system to target the emotion-creativity link with more precision than was previously possible. Thereby, it extends our work from interactive systems that influence the emotion-creativity link, to interactive systems that can influence the possible links between emotional intensity and creativity. This may be particularly interesting because it may enable some control over the degree to which such a system can augment or diminish creativity. To explore this potential, we *configured* the interactive system developed in study 3 to meet these demands. We hypothesize and experimentally demonstrate that the interactive system's ability to make the user's own ideas appear less or more original, can be used to condition expectations, and thereby help determine the intensity of positive and negative emotion. As such, this study builds on study 3, and extends it with a focus on how expectations can be conditioned such that we can investigate the link between the intensity of positive and negative emotions, and creativity during idea generation. A link between the intensity of positive and negative emotions, and creativity during idea generation, could, however, not be found. Thus, the contribution of the research presented in this chapter is a demonstration that an interactive system can be designed to use the function of cognitive appraisal processes in determining emotional intensity (*research objective O4*). However, its association with the emotion-creativity link requires further research. This answers part of *research question RQ2* positively, and part negatively.

7.2 Determining emotional intensity

Cognitive appraisal processes not only play a role in causing and differentiating emotion (section 6.2), they also help determine *emotional intensity* (Moors, 2013). That is, they help determine the degree to which an event drives changes in, and recruits, the emotion components (Brehm, 1999).

The intensity of an emotion is in part determined by the appraisal of an event against some frame of reference (Frijda, 2007; Siemer, 2007; Sonnemans & Frijda, 1994). Across the range of positive and negative emotions, e*xpectations*, the individual's beliefs about the probable outcome of an event or situation, appear to provide such a frame of reference (Brans & Verduyn, 2014; Ilgen, 1971). The more an event implies a deviation from the expected progress toward (goal-conduciveness), or away from (goal-obstructiveness), the individual's goals, the more intense the resulting positive or negative emotion is, and the stronger the change that is fed forward into the other emotion components (Carver & Scheier, 1990; 1998) (Figure 20). That is, if expectations are low, the same event is more likely to imply better progress toward the individual's goals, and cause more intense positive emotion, than when expectations are high (Ilgen, 1971). If expectations are high, the same event is more likely to imply worse progress away from the individual's goals, and cause more intense negative emotion than when expectations are low (Brans & Verduyn, 2014). Thus, expectations can possibly be used to influence the intensity of both positive and negative emotions.

There are of course many other factors that can influence the intensity of an emotion. Emotion regulation strategies such as distraction or removing oneself from the cause of an emotion, cognitive reappraisal, or suppression via motor expressions (chapters 4 and 5) can influence the intensity of an emotion when it is already caused (Gross, 1998). There are also many other cognitive appraisals that determine the intensity of an emotion when it is caused. Appraisal processes that are commonly found to determine intensity across a range of (positive and negative) emotions are the novelty of a situation (Sonnemans & Frijda, 1994), the unexpectedness of an event (Carver & Scheier, 1998; Siemer et al., 2007), and the importance of an event (Brans & Verduyn, 2014). Of these we can argue that novelty and unexpectedness share conceptual similarities (Carver & Scheier, 1998; Siemer et al., 2007; Sonnemans & Frijda, 1994). However, oftentimes determinants of emotional intensity are appraisals that are specific to one or only a few different emotions (Brans & Verduyn, 2014; Carver & Scheier, 1998; Siemer et al., 2007; Sonnemans & Frijda, 1994). For instance, the blameworthiness of a person during anger influences the intensity of anger (one might be less angry at a child than at an adult depending on the obstruction caused and the subsequent blame that is assigned), but much less (if any) for other emotions (Sonnemans & Frijda, 1994). Because expectations have previously been show to provide a frame of reference against which appraisals determine the intensity of positive and negative emotions (Carver & Scheier, 1998), we focus on the links between expectations, positive and negative emotion, and creativity during idea generation in this study. We will expand on how we further conceptualise using expectations as a way to help determine the intensity of an emotion.

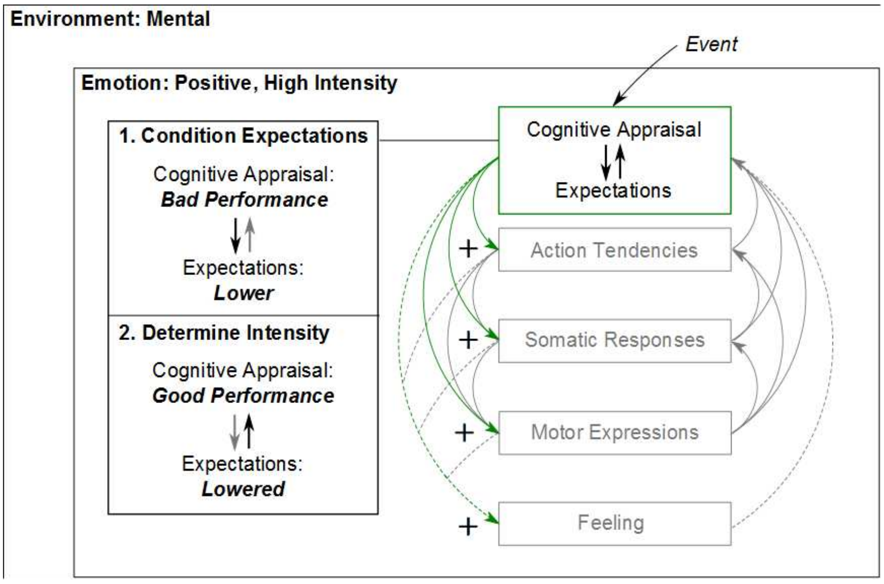

Figure 20 Schematic of the function of cognitive appraisal processes in determining emotional intensity. Cognitive appraisal processes can help condition expectations (e.g. bad performance lowers expectations), which provides a frame of reference against which subsequent events are appraised. The way in which an appraised event deviates from expectations (e.g. good performance with low expectations, as opposed to good performance with high expectations), determines the intensity of the resulting emotion (e.g. good performance when expectations are low results in more intense positive emotion than good performance when expectations are high), by determining not only the type of emotion (green arrows), but also the degree of change in the emotion's components (+).

The cognitive appraisal processes that cause positive and negative emotions, reciprocally condition the expectations that help determine the intensity of these emotions (Carver & Scheier, 1990; 1998) (Figure 20). This is because expectations are formed, in part, based on how often and how recently particular events happen, and based on how these events are appraised, in particular situations (Weiner, 1985). That is, if an event, in a particular situation, repeatedly implies better progress toward an individual's goals, expectations will be raised for subsequent similar situations (Carver & Scheier, 1990; 1998). Therefore, if an event repeatedly implies more progress away from the individual's goals, expectations will be lowered for subsequent similar situations. The degree to which expectations are lowered or raised depends in part on the degree an event implies deviations from one's initial expectations (Carver & Scheier, 1990; 1998). Note that other factors (e.g. the amount of available resources, or optimism) can also influence expectations. See (Weiner, 1985; Wigfield & Eccles, 2000) for overviews.

The effects of cognitive appraisal processes on expectations is conditional upon at least two additional factors (Carver & Scheier, 1990; 1998; Schunk, 1989; Wigfield & Eccles, 2000). We assume that these need to be taken into account when designing an interactive system that makes use of the reciprocal relation between cognitive appraisal processes and expectation, in determining emotional intensity.

First, whether people change their expectations or not, depends in part on the cause that is attributed to an event (Schunk, 1989; Wigfield & Eccles, 2000). That is, the cause of an event should justify changing expectations. For instance, expectations are raised when an event implies an increase in the progress toward an individual's goals is caused by the individual's own abilities. However, when the same event is caused by chance, the event has no implications for the accuracy of any existing expectations, and will not influence these (Schunk, 1989).

Second, people often engage in different behaviours to provide information about whether a change in expectations is justified (cf. Roseman, 2011). For instance, if task performance is worse than expected, people do not usually lower their expectations right away, people rather tend to invest more motivational resources first (e.g. through increasing persistence) (Carver & Scheier, 1990; 1998). Only if this still does not lead to sufficient improvement, do they lower their expectations. Similarly, when performance is better than expected, people do not raise their expectations right away, but instead wait and see whether performance remains better than expected (Carver & Scheier, 1990; 1998).

Interactive systems that are designed to hack into the function of cognitive appraisal processes in determining emotional intensity are relatively scarce. This is because the majority of existing interactive systems are not designed to, nor can be designed to, determine emotional intensity. Rather, they are designed to help cause one particular emotion versus another (cf. section 2.3.1). Following the arguments used in study 3, our approach is closer to technologies that explicitly make use of reward and punishment, such as gaming technologies (section 6.2). Because such technologies implicitly make use of this function of cognitive appraisal processes, they can also be used to determine emotional intensity (cf. Koster, 2013). For instance, varying the difficulty of a game can make it easier or more difficult to attain a certain amount of points. It follows that difficulty can be used to condition expectations. For instance, a subsequent change in difficulty might influence the progress toward or away from an individual's goals during the game, and influence emotional intensity accordingly (cf. Järvinen, 2007; Tijs et al., 2008). This indicates that interactive systems can be used to hack into cognitive appraisal processes to determine emotional intensity. However, interactive systems that explicitly leverage the function of cognitive appraisal processes in determining emotional intensity are novel.

In this study we develop such a system, by explicitly enabling an interactive system to manipulate the cognitive appraisal processes that cause positive and negative emotion during idea generation, in order to condition expectations, and thereby determine the intensity of the positive and negative emotions caused.

7.3 Determining emotional intensity to augment creativity

To develop a theoretical basis for an interactive system that makes use of the function of cognitive appraisal processes to determine emotional intensity, within a creative context, we unify the above assumptions about the role of appraisals in conditioning expectations, and the role of expectations in determining emotional intensity, with the particulars of the appraisals that cause positive and negative emotions during idea generation, i.e. the results from study 3 (chapter 6) (Figure 21).

The results from study 3 showed that during idea generation, the appraised originality of one's own ideas causes positive and negative emotions. It follows from the above section that the appraised originality of one's own ideas, can condition one's expectations about how likely one is to generate original or unoriginal ideas in subsequent idea generation tasks (Figure 21). These expectations provide a frame of reference against which these appraisal processes determine the intensity of positive and negative emotions during idea generation. For instance, generating more original ideas, rather than more unoriginal ideas, may lead people to raise their expectations about their ability to generate original ideas. When this is followed at a later stage by generating more unoriginal ideas, the resulting negative emotions will be more intense, than when they initially also generated more unoriginal ideas. Determining the intensity of positive and negative emotions, may also enable some control over the degree with which emotions influence creativity (cf. sections 2.2.1.1, 2.2.1.2). An interactive system that targets the appraisal of how original or unoriginal one's own ideas are, such as the interactive system developed in study 3 (section 6.4), may be able to help determine emotional intensity, and therefore the degree to which it affects the emotion-creativity link. In this study we develop such an interactive system.

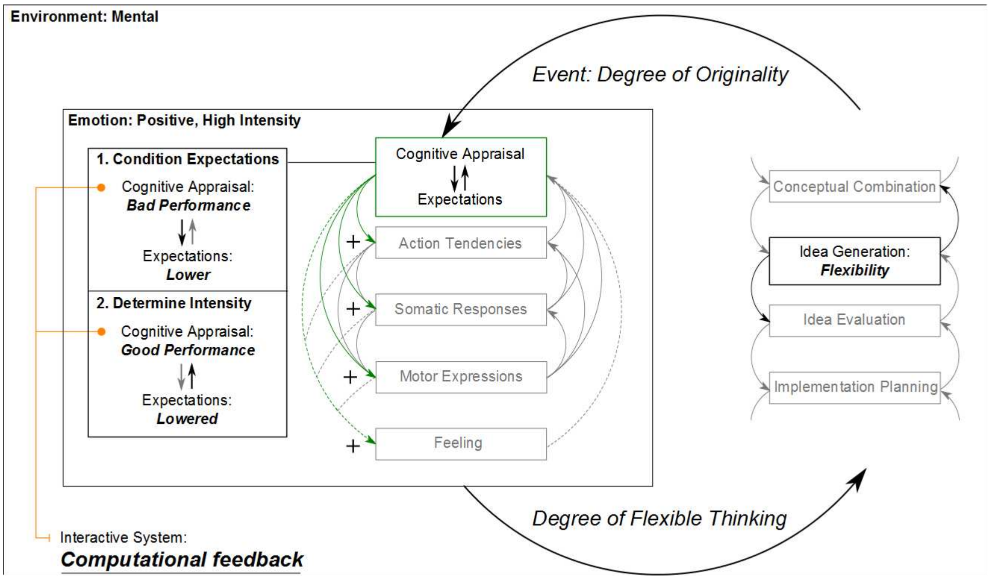

Figure 21 A schematic of our use of cognitive appraisal processes to influence the link between emotional intensity and creativity. The figure shows the function of cognitive appraisal processes in determining the intensity of a positive emotion (left, green arrows, +), the influence of the intensity of positive emotion on creativity during idea generation (right), and the way this configuration of the interactive system developed in study 3 makes use of this relationship to influence the emotion-creativity link (bottom-left).

In section 2.3.3.2 we discussed possible limitations of interactive systems that attempt to influence the emotion-creativity link. In section 6.3 we discussed how hacking into cognitive appraisal processes is one particular approach to tackle these limitations. In this study, we aim to build on the latter approach, by enabling this interactive system with the ability to determine the intensity of positive and negative emotion. We believe that *interactive systems* that target cognitive appraisal processes to determine emotional intensity might help to further explore the relationship between emotion and creativity with more precision than what is possible with the previously developed approaches. In particular, because the relationship between the intensity of positive emotions, and creativity, is not well understood (cf. Akhbari Chermahini & Hommel, 2012b; Baas et al, 2008; Davis, 2009).

To further develop and investigate these theoretical conjectures, we will reconfigure the proof-of-concept interactive system developed in study 3 (section 6.4) to condition expectations about the originality of one's own ideas, in order to help determine the intensity of positive and negative emotion one experiences.

7.4 Configuring the interactive system

In study 3 we developed an interactive system that provides real-time and believable feedback about how original a user's ideas are (chapter 6). Manipulation of this feedback, by making the users' ideas appear less (*negative feedback manipulation*) or more original (*positive feedback manipulation*) than people typically rate them to be, was shown to influence the cognitive appraisal processes that form part of positive and negative emotions, and help cause these positive and negative emotions accordingly.

We assume that a new *configuration* of this same interactive system can also be used to help determine emotional intensity, by making use of the function of cognitive appraisal processes in conditioning people's expectations about how likely they are to generate original or unoriginal ideas. We believe that to observe this particular capability of this interactive system, it has to be used only twice, with a similar task, where the first task enables the system to condition the user's expectations, and the second task enables the system to determine emotional intensity.

The systems' ability to positively and negatively manipulate feedback about the originality of the user's own ideas, can be used to enable the following:

1. Negative followed by negative feedback manipulation conditions low expectations first, but as people become accustomed to these expectations, they come to believe they are doing as expected, leading to less intense negative emotions.
2. Positive followed by negative feedback manipulation conditions high expectations first, and then leads people to believe they are doing much worse than they have come to expect, leading to more intense negative emotions.
3. Negative followed by positive feedback manipulation conditions low expectations first, and then leads people to believe they are doing much better than they have come to expect, leading to more intense positive emotions.
4. Positive followed by positive feedback manipulation conditions high expectations first, but as people become accustomed to these expectations, they come to believe they are doing as expected, leading to less intense positive emotions.

This influence of the interactive system on expectations, and thereby emotional intensity, is conditional upon the system's ability to: 1) let the user believe that the system's feedback has implications for the expectations about his or her own creativity abilities (cf. Schunk, 1989), which is likely to be the case, as was shown in the manipulation checks in study 3 (section 6.6); and, 2) allow sufficient time for the user to interact with the system in a manner that provides them with information about whether a change in expectations is justified (cf. Carver & Scheier, 1990; 1998). With regard to the latter we assume that the time of task used for the AUT in our previous studies, would be sufficient time to justify a change in expectations.

The ability of the interactive system to use the function of cognitive appraisal processes in determining the intensity of positive and negative emotion can possibly enable further exploration of the emotion-creativity link. In this way, it is intended that increased control over the intensity of these emotions can enable the system to influence the degree to which negative emotions are used to (possibly) diminish creativity (section 2.2.1.2), and positive emotions are used to augment creativity (section 2.2.1.1).

7.4.1 Hypotheses

To investigate these theoretical conjectures with the previously developed and now reconfigured interactive system, we will test the following hypotheses experimentally (Table 15).

#	Hypothesis
H1	*The order in which feedback is made more positive or negative determines the intensity of positive and negative emotion by conditioning people's expectations about their ability to generate original ideas.*
H2	*The order in which feedback is made more positive or negative influences the degree to which people are able to generate original ideas via the feedback's influence on the intensity of positive and negative emotion.*

Table 15 Hypotheses for study 4.

7.5 Method

To test the hypotheses and thereby evaluate experimentally the interactive system, we used a between-subject design. Each participant did two idea generation tasks, while using the interactive system, during which the interactive system manipulated the feedback it generated about the originality of the participants' own ideas. Each participant was exposed to one of the following orders in which the feedback manipulations were administered:

1. Negative feedback manipulation in task 1 and in task 2.
2. Positive feedback manipulation in task 1, followed by negative feedback manipulation in task 2.
3. Negative feedback manipulation in task 1, followed by positive feedback manipulation in task 2.
4. Positive feedback manipulation in task 1 and in task 2.

Analysis was done only on the results obtained after the second task, which justifies using a between-subject, rather than a within-subject design. A cover story was used to hide the true purpose of the study (section 6.5). Both the feedback manipulations and the subjects used during the tasks were randomized to prevent research bias.

7.5.1 Participants

In total, 59 people (49 females, 10 males, M_{age}=29, SD_{age}=6.97) participated in our study. Two participants guessed the purpose of the study, one participant admitted not to have paid attention to the feedback, and two participants admitted to have tried to game the interactive system by typing in bizarre ideas. As these may threaten the internal validity of the results, we removed these cases from the analysis, which resulted in 55 usable cases. Furthermore, care was taken to ensure that no participants were recruited that previously participated in study 3. The vast majority of the participants were students or employees of City University London.

7.5.2 Materials and measurements

7.5.2.1 Creative tasks

To gather data from which we could assess the participant's creativity during idea generation, we again used the AUT (section 3.3.1). Participants were instructed to "*…come up with as many, diverse, and original uses for the common object as you can*", within 4 minutes. See section 4.5.2.1 for the underlying rationale for the way these instructions were framed. A different object (either a brick or a paperclip) was used for each task. Presentation order was randomized.

7.5.2.2 Assessment of creativity

To assess the *originality* of the ideas the participants generated during the AUT we again used the system's own unmanipulated originality estimates (section 6.5.2.2). The amount of ideas generated in the second AUT that were above the 75^{th} percentile rank was counted for each individual (24% of the total amount of ideas in this study). We then divided the total amount of ideas, by the amount of original ideas to correct for fluency. See section 5.5.2.2 for the reasons for using this correction, and section 6.5.2.2 for possible sources of measurement error that are introduced by automating the way originality is assessed.

7.5.2.3 Assessment of emotional intensity

The participants used a Likert scale to self-report the satisfaction (1=not satisfied, 9=very satisfied) and frustration (1=not frustrated, 9=very frustrated) they had experienced during each task (section 3.3.3). We assume that emotional intensity is reflected in the degree to which people rate being not frustrated – very frustrated, and not satisfied – very satisfied. For instance, a central tendency closer towards very satisfied is interpreted as a higher intensity positive emotion than a central tendency closer toward not satisfied. Note that we used the same approach to self-report as described in study 3 where we did not focus on measuring emotional intensity (section 6.5.2.3). However, because the used scales are dimensional we can also use these to study emotional intensity (e.g. Brans & Verduyn, 2014; Siemer et al., 2007). Emotion was assessed after the second task. See section 4.5.2.3 for the general rationale for the way self-report was implemented.

7.5.2.4 Assessment of expectations

To assess whether the feedback manipulations influenced the participants' expectations, they were asked to use a Likert scale to rate the degree to which their task performance deviated from their expectations (1=much worse than expected, 9=much better than expected). Note that the same scale was used as a manipulation check in study 3 (section 6.5.2.4). Expectations were assessed after the second task. We explicitly did not check for the expectations participants had prior to each task because we were unsure whether people would be able to self-report these in a manner that would yield valid results. Instead, we assumed that the degree to which performance violated their expectations, would be easier to report (cf. Carver & Scheier, 1990; 1998), and would therefore reduce measurement error.

7.5.2.5 Manipulation check

One manipulation check was carried out to support the internal validity of the study design (section 3.3.4). We used a Likert scale to assess whether there were differences amongst the feedback manipulations in the system's perceived reliability (1=very unreliable, 9=very reliable). This was to check whether the feedback influenced emotion as intended. This was checked after the second task.

7.5.3 Procedure

Upon arrival the participants were seated at a computer and introduced to the study and its procedure. A cover story was used that informed the participants that we were testing *"... the efficacy of using computer supported idea evaluation,"* but we withheld information about the actual experimental conditions until the end of the experiment. Informed consent was signed, and the participants filled in a brief questionnaire to collect personal data (age, gender). We then explained that they would do two AUTs during which our interactive system would provide feedback about the originality of each idea they came up with and provided instructions about the AUT. We emphasised that their goal was to "*…come up with as many, diverse, and original uses for the common object as you can*" during each task. For the system's feedback we emphasized that participants should *"… use the feedback as a guide that helps you during your idea generation process."* A picture of the common object used during each AUT was shown just before each task. The common object and feedback manipulations were randomised automatically by the interactive system, after which the task started, during which time they generated and typed in their ideas, and received manipulated feedback about the originality of the ideas they were generating, in real-time. Thus, this marks the moments at which we believe the system manipulates the participant's expectations, emotions, and emotional intensity. Each task took exactly 4 minutes, which was timed internally by the interactive system. After these 4 minutes ended the interactive system automatically prevented the participants from filling in more ideas automatically. After the first task, the system prompted a request to start with the second task when ready. After the second task, the interactive system prompted a request to fill in a questionnaire. This questionnaire contained the measurement instruments used to assess emotion and carry out the manipulation checks. After the experiment ended, the participants were debriefed. There the true purpose of the study was explained, and we asked whether the participants had guessed this purpose, had tried to game the feedback during some tasks, or had other problems using the system. To compensate the participants for their effort, we handed them a £5 voucher for a large online retailer, and a chocolate bar. A graphic representation of the procedure is presented in Figure 22.

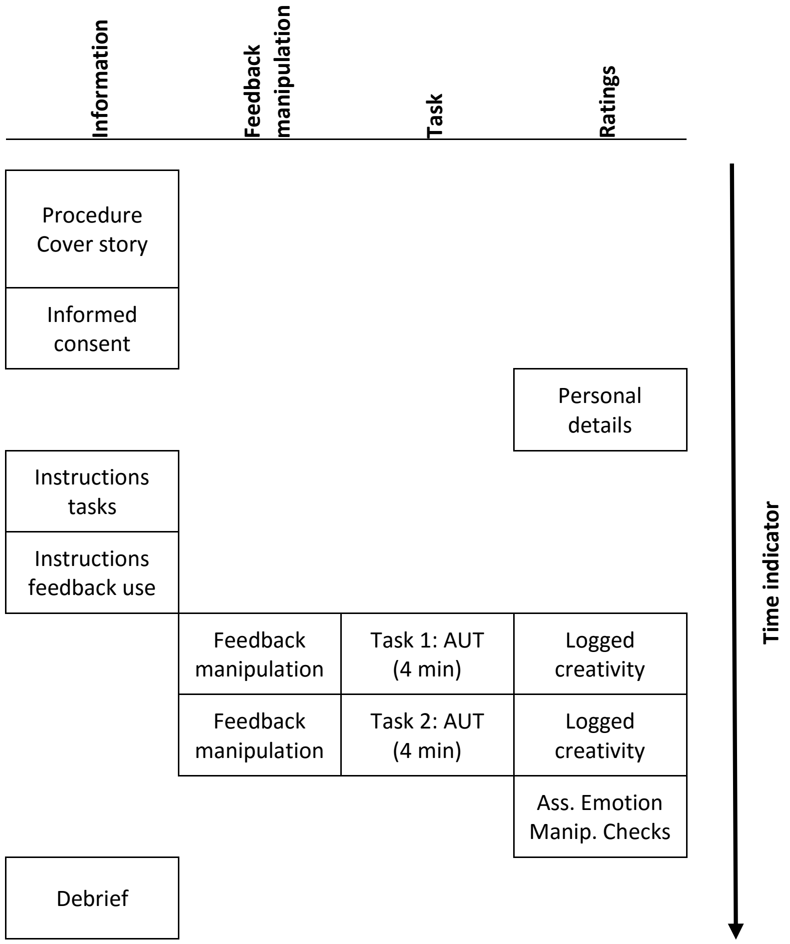

Figure 22 Graphic representation of the order and timing of information, when the feedback manipulations were used to influence the appraisals of the user's own ideas (and subsequently their expectations, emotions, and the intensity of their emotions), the tasks performed, and the ratings used in the procedure.

7.6 Results

We first carried out a manipulation check so we could get an indication of whether the manipulations of the feedback provided by the interactive system influenced the way participants appraised the originality of their ideas as intended. This was done by submitting the perceived reliability of the system's feedback as a DV to a one-way ANOVA, with the feedback manipulations, i.e. the four orders in which the feedback manipulations were administered, as the IV. The results suggested that there was no significant effect of the feedback manipulations on perceived reliability, $F(3, 50)=.14$, $p=.937$. This indicates that the feedback manipulations were likely to have the intended effect.

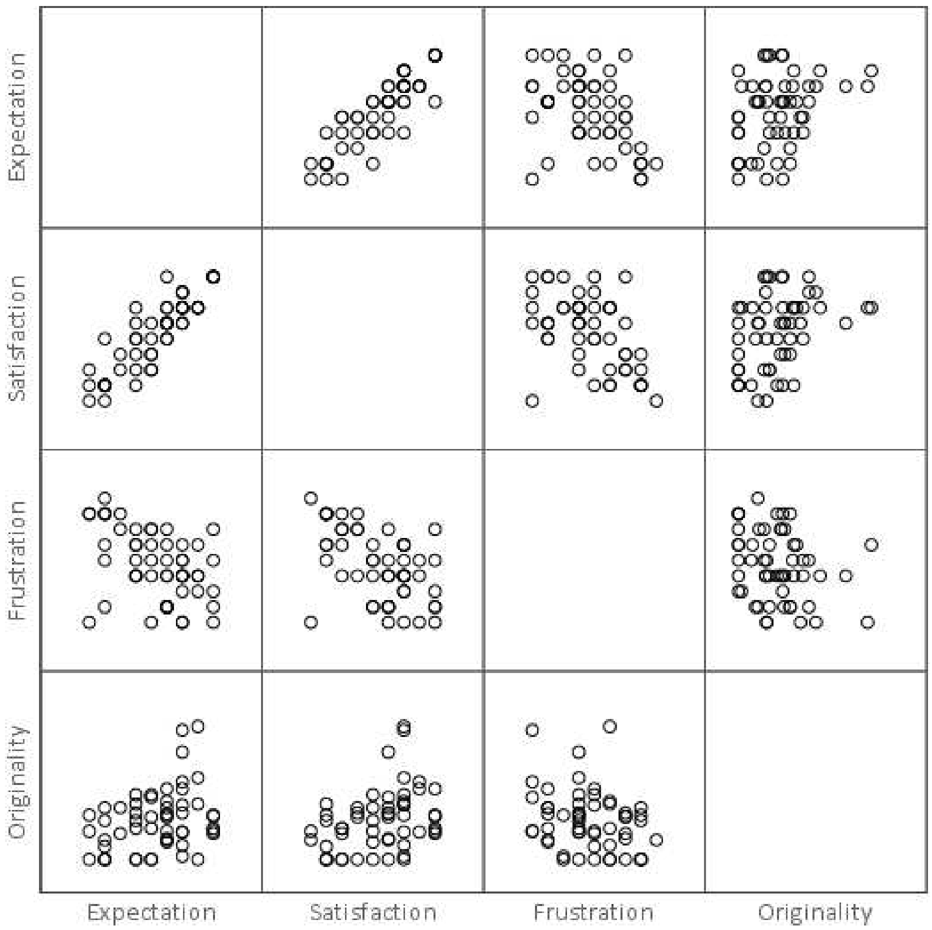

Figure 23 Scatterplot matrix of the dependent variables expectation, satisfaction, frustration, and originality.

DV	1.	2.	3.	4.
1. Expectation	-			
2. Satisfaction	.881**	-		
3. Frustration	-.449**	-.521**	-	
4. Originality	.334*	.360**	-.275*	-

*Table 16 Pearson correlation coefficients for the DVs originality, satisfaction, frustration, and expectation. *p<.05, **p<.001.*

To test whether there were a*ssociations between expectations, emotional intensity, and creativity* across the experimental conditions, we performed several correlations (Table 16).

To test whether there was an association between expectations and the intensity of positive (satisfaction) and negative emotions (frustration), across the experimental conditions, we correlated the expectation, satisfaction, and frustration ratings. The results suggested a significant positive correlation between expectations and the intensity of satisfaction, and a significant negative correlation between expectations and the intensity of frustration. Based on the correlations alone there appears to be a relationship between the deviation from expectations and the intensity of positive and to some extent negative emotions.

To test whether there was an association between emotion and creativity across the experimental conditions, we also correlated the intensity of satisfaction and frustration, with originality. The results suggested that there was a significant positive correlation between originality and the intensity of satisfaction, and a significant negative correlation between originality and the intensity of frustration. This indicates that positive, rather than negative emotion associates with augmented creativity.

Feedback manipulation		Expectation	Satisfaction	Frustration	Originality
First task	Second task				
Negative	Negative	5.14 (2.38)	5.14 (2.54)	4.86 (2.07)	.245 (.141)
Positive	Negative	4.00 (2.00)	3.83 (2.08)	6.25 (1.42)	.145 (.129)
Negative	Positive	7.43 (1.34)	7.00 (1.57)	3.71 (1.73)	.297 (.244)
Positive	Positive	4.57 (2.03)	5.50 (2.14)	4.07 (2.73)	.305 (.223)

Table 17 Means and standard deviations (between parentheses) for expectation, satisfaction, frustration, and originality (DVs), for each of the feedback manipulations (IV).

To test whether there was an effect of the way the interactive system was used, on *expectations*, *emotional intensity*, and *creativity* individually, we submitted expectation, satisfaction, frustration, and originality individually as DVs to a one-way ANOVA, with the feedback manipulations as the IV. The descriptive statistics are presented in Table 17, a scatterplot matrix of the dependent variables is presented in Figure 23.

The results suggested that there was a significant effect of the feedback manipulations on *expectations*, $F(3, 53)=7.83$, $p<.001$, $\eta^2=.320$. Pairwise comparisons of the feedback manipulations (using Fisher's least significant difference – no corrections applied) showed that negative followed by positive feedback manipulation influenced people to believe they did better than they expected, when compared to positive followed by negative, and positively or negatively manipulating feedback in both tasks (Figure 24, Table 18, Expectations). Positive followed by negative feedback manipulation influenced people to believe they did worse than they expected, when compared to negative followed by positive, and positively manipulating feedback in both tasks, but not when compared to negatively manipulating the feedback in both tasks. This indicates that the interactive system can use cognitive appraisal processes to condition people's expectations, but only with the manipulations that were designed to target the intensity of satisfaction.

The results also suggested that there was a significant effect of the feedback manipulations on the *intensity* of satisfaction, $F(3, 53)=4.96$, $p=.004$, $\eta^2=.229$. Pairwise comparisons (using Fisher's least significant difference – no corrections applied) showed that negative followed by positive feedback manipulation heightened the intensity of satisfaction, when compared to positive followed by negative, and negatively manipulating feedback in both tasks, but the results were less clear when compared to positively manipulating the feedback in both tasks (Figure 24, Table 18, Satisfaction). This indicates that the feedback manipulations that were designed to target the intensity of satisfaction were effective.

The results also showed a significant effect of the feedback manipulations on the intensity of frustration, $F(3, 53)=3.76$, $p=.016$, $\eta^2=.184$. Pairwise comparisons (using Fisher's least significant difference – no corrections applied) showed that positive followed by negative feedback manipulation heightened the intensity of frustration, when compared to negative followed by positive, and positively manipulating the feedback in both tasks, but not when compared to negatively manipulating the feedback in both tasks (Figure 24, Table 18, Frustration). This indicates that the feedback manipulations that were designed to target the intensity of frustration were also effective.

As such, the results indicate that varying the order of the feedback manipulations across tasks leads to changes in 1) expectations (but only for the manipulations designed to target the intensity of satisfaction), 2) the intensity of satisfaction, and 3) the intensity of frustration. The results also indicate a positive correlation between expectations and the intensity of positive emotion. Therefore, we assume that the order in which feedback is made more positive or negative determines the intensity of positive and negative emotion by conditioning people's expectations about their ability to generate original ideas. That is, the proof-of-concept interactive system can be used to influence the intensity of positive emotions during a creative idea generation task. This supports hypothesis H1, but only for positive emotions (satisfaction).

The results suggested furthermore that there was no overall significant effect of the feedback manipulations on *creativity,* as measured by originality, $F(3, 53)=1.83$, $p=.154$, $\eta^2=.099$. Pairwise comparisons (using Fisher's least significant difference – no corrections applied) showed that negative followed by positive feedback manipulation augmented originality, when compared to positive followed by negative, but not when compared to positively or negatively manipulating feedback in both tasks (Figure 24, Table 18, Originality). Positive followed by negative feedback manipulation diminished originality, when compared to negative followed by positive, and positively manipulating feedback in both tasks, but not when compared to negatively manipulating feedback in both tasks. This indicates that the feedback manipulations designed to influence the intensity of frustration had a negative effect on originality. However, the expected effect of the feedback manipulations designed to target the intensity of satisfaction did not yield observable differences in the ability of the participants to generate original ideas.

Because the results indicate that the order in which the feedback manipulations are applied caused changes in 1) expectations (but only for the manipulations aimed at targeting the intensity of satisfaction), 2) the intensity of both satisfaction and of frustration, 3) to some degree in originality (but only negatively and for the manipulations aimed to targeting the intensity of frustration), we cannot provide a clear-cut explanation for the manner in which the order of the feedback is made more positive or negative influences the degree to which people are able to generate original ideas. This despite the result that there is a correlation between originality and satisfaction and frustration. This suggests that the interactive system in its current configuration cannot be used to influence creativity during idea generation, at least not in a positive manner. Therefore, these results do not support hypothesis H2.

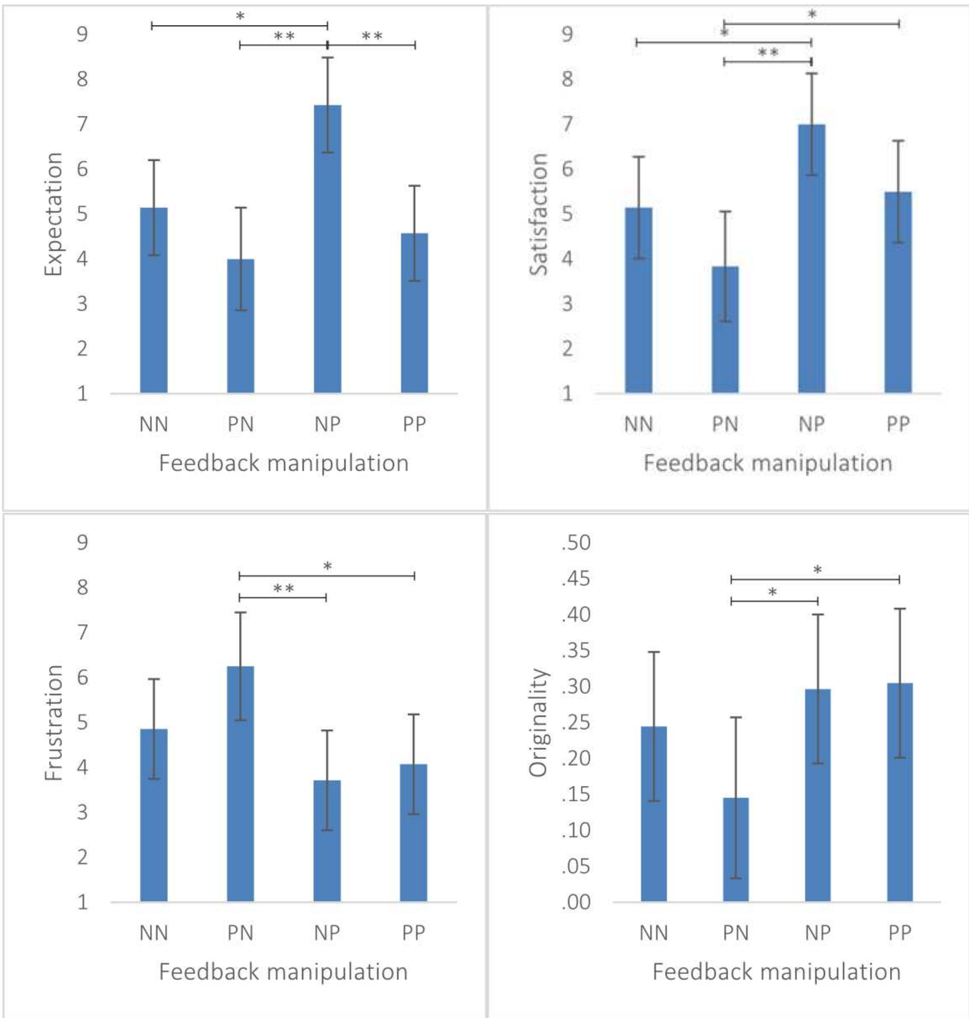

*Figure 24 Estimated marginal means, 95% confidence intervals (error bars), and p-values for pairwise comparisons (Fisher's least significant difference – no correction applied for post-hoc testing) for expectation, satisfaction, frustration, and originality (DVs), for each of the feedback manipulations (IV). NN=negative feedback manipulation in both tasks, PN=positive followed by negative feedback manipulation, NP=negative followed by positive feedback manipulation, PP=positive feedback manipulation in both tasks. * p<.05, ** p<.001*

DV	I	J	Mean Difference (I-J)	P-value
Expectation	N	NP	-2.29	.003
		PN	1.14	.147
		PP	.57	.447
	NP	NN	2.29	.003
		PN	3.43	.000
		PP	2.86	.000
	PN	NN	-1.14	.147
		NP	-3.43	.000
		PP	-.57	.465
	PP	NN	-.57	.447
		NP	-2.86	.000
		PN	.57	.465
Satisfaction	NN	NP	-1.86	.024
		PN	1.31	.121
		PP	-.36	.656
	NP	NN	1.86	.024
		PN	3.17	.000
		PP	1.50	.066
	PN	NN	-1.31	.121
		NP	-3.17	.000
		PP	-1.67	.048
	PP	NN	.36	.656
		NP	-1.50	.066
		PN	1.67	.048
Frustration	NN	NP	1.14	.150
		PN	-1.40	.093
		PP	.79	.320
	NP	NN	-1.14	.150
		PN	-2.54	.003
		PP	-.36	.650
	PN	NN	1.39	.093
		NP	2.54	.003
		PP	2.18	.010
	PP	NN	-.79	.320
		NP	.36	.650
		PN	-2.18	.010
Originality	NN	NP	-.05	.477

		PN	.10	.197
		PP	-.06	.413
	NP	NN	.05	.477
		PN	.15	.050
		PP	-.01	.913
	PN	NN	-.10	.197
		NP	-.15	.050
		PP	-.16	.041
	PP	NN	.06	.413
		NP	.01	.913
		PN	.16	.041

Table 18 Pairwise comparisons (Fisher's Least Significant Difference - no corrections applied) reported by means of the mean differences between the independent variables and the p-values for the dependent variables expectation, satisfaction, frustration, and originality. The independent variables are abbreviated as follows: NN=negative feedback manipulation in both tasks, PN=positive followed by negative feedback manipulation, NP=negative followed by positive feedback manipulation, PP=positive feedback manipulation in both tasks.

7.7 Discussion

Our findings demonstrate that an interactive system can be designed to hack into the function of cognitive appraisal processes in emotion, to help determine emotional intensity. However, the used configuration of the interactive system did not yield any observable positive effects on creativity during idea generation (*research objective O4*).

With regard to the effects of the interactive system on the link between expectations and the intensity of positive (satisfaction) and negative (frustration) emotions. The results indicate that the order of the feedback manipulations can cause changes in expectations. However, this only happened when negative was followed by positive feedback manipulation (which is designed to influence the intensity of positive emotion). The results also indicate that the order of the feedback manipulations can influence the intensity of positive and to some extent of negative emotion.

As discussed, the results suggest a positive correlation between expectations and the intensity of positive emotion. Therefore, we assume that the order in which feedback is made more positive or negative can be used to determine the intensity of positive and negative emotion. This, we assume is done by conditioning people's expectations about their ability to generate original ideas. These findings suggest that the used configuration of the interactive system can be used to influence the relationship between expectations and the intensity of positive emotion, but not between expectations and the intensity of negative emotion. Our findings therefore appear to support hypothesis H1, but for positive emotions only.

With regard to the link between expectations, the intensity of positive and negative emotion, and creativity during idea generation (originality). The results indicate that the order in which the feedback manipulations are applied caused changes in expectations in the subsequent task. This however, only appeared to hold for negative followed by positive feedback manipulation (which was used to influence the intensity of positive emotion). Complementarily, the results indicated that this influenced the intensity of positive emotion and the intensity of negative emotion. However, the manipulations only influenced creativity negatively (when positive feedback manipulation was followed by negative feedback manipulation), and did not influence creativity as expected via the effects of the feedback manipulations on expectations. Moreover, the differential effects of the feedback manipulations on the intensity of positive emotion did not yield any observable differences in creative thinking ability during idea generation. Therefore, we cannot provide a clear-cut explanation for the manner in which the order of the feedback is made more positive or negative influences the degree to which people are able to generate original ideas. This suggests that the interactive system in its current configuration cannot be used to influence the creativity during idea generation, at least not in a positive manner. Therefore, these results do not support hypothesis H2.

There were of course also limitations to this study that have some bearing on the validity of the claims that can be made about the results. One major factor was the lack of control groups. We consider the use of the same feedback manipulation in both AUTs as a way of controlling for the fact that variation in feedback manipulation should lead to differences in emotional intensity. However, as in study 3 (section 6.7), we did not use a control condition where participants were assigned to a non-feedback situation (i.e. participants would use the same interactive system, but the system would not provide feedback on their ideas). Therefore, and given the similarity between these two studies, the same limitations apply. We therefore refer to the discussion in chapter 6 (section 6.7) for a detailed discussion of the limitations of a lack of this type of control group for the conclusions that can be drawn from both studies.

In addition, there is also one particular limitation that pertains to this study only. That is, we did not include neutral feedback manipulation as a control condition such as in study 3 (chapter 6). Inclusion could have provided us with a more fine-grained perspective on the effects of the feedback manipulations on emotional intensity. For instance, such a study could indicate that amount of deviation in expectations is linearly responsible for self-reported intensity of positive emotion. This in turn could have provided a more detailed account of how the variation of feedback manipulations over time influenced the emotion-creativity link. Possibly, such a study would have revealed that there is a curvilinear relationship between the intensity of positive emotion and creativity during idea generation, i.e. that this relationship is best described as an inverted U-shape (cf. Akhbari Chermahini & Hommel, 2012b). If the latter is the case, then not including a control group is a likely cause of our inability to find a clear relationship between positive emotion and creativity such as in our previous studies (chapters 4, 5, and 6). However, not including the neutral condition in such a manner did not allow us this more fine-grained perspective, which limits the conclusions we can draw from the collected data.

Because recent findings indicate that the relationship between the intensity of positive emotion and creativity during idea generation is curvilinear (Akhbari Chermahini & Hommel 2012b), a different method should likely be used than we did in this study. Rather than using feedback manipulation as a categorical variable, we suggest to uniformly randomise the degree to which the feedback is made more positive or negative over time. One could use curve estimation to find out whether variations in feedback manipulation yield differences in a manner that is curvilinear, and thereby provide the required fine-grained perspective on the link between the intensity of positive emotion and creativity during idea generation that is required to uncover any curvilinearities.

We also wish to point out that our decision to measure the intensity of positive and negative emotion as the intensity of satisfaction and frustration may have introduced confounding factors into our assessment of the effects of our interactive system on the emotion-creativity link. For instance, since we did not measure arousal or motivational direction we cannot rule out that the observed effects on the emotion-creativity link (or lack thereof) were explained better by these unmeasured arousal effects (section 2.2.2.1) or changes in motivational direction and their intensity (section 2.2.2.2 and

2.2.2.3). Thus, we cannot rule out that there were confounded factors that (also) explained the found influences of the interactive system on the emotion-creativity link.

It is also worth noting that the sample size used in this study is on the low side for the used study design, which might make the results more sensitive to individual differences among the participants in relation to the assessed influence on emotion and creativity, and therefore increase the chance of type I and type II errors, which threatens the validity of any conclusions that were drawn based on the study results.

Furthermore, the repeated use of the AUT might have introduced learning effects into the data obtained (also see section 6.7). Although we only used the data from the second task, and therefore no differences in learning effects would be expected, one could argue that it does introduce the effects of learning itself into the data, which threatens the construct validity of the AUT used. We recommend that the reader takes this into account.

The results do however also point toward some interesting limitations in the *effectiveness* of our interactive system, with regards to its ability to determine the intensity of positive and negative emotions, and subsequently its ability to influence the link between emotional intensity and creativity during idea generation that could form the basis for any future work.

First, the ability of the interactive system to determine the intensity of positive emotion could be explained by the way the feedback manipulations conditioned people's expectations. However, its effect on expectations could not explain the effect of the interactive system on the intensity of negative emotion. Furthermore, the manipulations used to cause differences in the intensity of negative emotion also diminished creativity during idea generation. This suggests that differences in the intensity of negative emotions were found, but not all via the mechanisms based on which the interactive system was conceived. Thus, this indicates that the mechanisms that underlie the effects of the system on negative emotion and its subsequent negative effect on creativity require an alternative explanation.

We suspect that people are possibly more willing to accept situations in the way they are presented when they are in line with their current goals (cf. Siemer, 2005). Receiving more positive feedback than expected might be more in line with the goals people have during an idea generation task, e.g. attaining good performance, which lead people to attribute the cause of this more positive feedback to their own abilities more easily. In contrast, receiving more negative feedback than expected suggests a conflict with these goals in which situation people might be more reluctant to accept the feedback as relevant to their own abilities leading them to attribute the cause of the negative feedback externally, e.g. by blaming the interactive system. The latter would explain why people reported more intense negative emotions and why no effect of these emotions on the emotion-creativity link was found, because these emotions were not about creativity, but rather about something else.

Second, the current ability of the interactive system to make use of the link between expectations, emotional intensity, and creativity can theoretically only extend to the *relationship between expectations, the intensity of positive emotions, and creativity* during idea generation. Although the ability of the interactive system to use the function of cognitive appraisal processes in positive emotion, to determine the *intensity* of positive emotions, was clear, it did not augment *creativity.* Several possible explanations might be offered here.

It might be that negatively manipulating the feedback in both tasks, increases effort (Carver & Scheier, 1990; 1998), which might augment creativity though another mechanism than the one assumed in this study (e.g. de Dreu et al., 2008). This can explain the minor differences found between negative followed by positive feedback manipulation, and negatively manipulating the feedback in both tasks. It might also be that positively manipulating the feedback in both tasks led to carry over effects, where positive emotion caused in the first task was sustained in the second and therefore could benefit creativity throughout the second task (Fernández-Abascala & Martin Díaz, 2013). Whereas, negative followed by positive feedback causes more intense positive emotion but may only start to augment creativity later in the task.

However, we believe that it is more plausible that negative followed by positive feedback manipulation caused positive emotion with too much intensity, and positively manipulating the feedback in both tasks, caused positive emotions with too little intensity to lead to differences in creativity. This could possibly be explained by the previously mentioned *curvilinear relationship* between the intensity of positive emotion and creativity (Akhbari Chermahini & Hommel, 2012b). That is, it has been argued that low intensity positive emotion causes too little, and high intensity positive emotion causes too much flexibility, which makes it difficult to focus sufficiently to generate ideas (Baas et al., 2008). Positive emotions of moderate intensity are in a sweet spot where there is increased flexibility, but still sufficient ability to focus on the task at hand. We suspect that the current configuration of the interactive system did not target moderate intensity positive emotion but instead only low and high intensity positive emotions yielding no observable differences in creativity. As such, the potential ability of our interactive system to make use of the *relationship between the intensity of positive emotion and creativity* during idea generation requires more work.

Thus, the contribution of the research presented in this chapter is a demonstration that an interactive system can be designed to use the function of cognitive appraisal processes in determining emotional intensity. We assume that the demonstration that cognitive appraisal processes can be used to determine emotional intensity, partly, positively answers *research question RQ2*. However, the lack of consistent findings of the influence of the system on the relationship between the intensity of positive and negative emotions and creativity during idea generation negatively answers part of *research question RQ2*.

The next step is to investigate the suggested potential limitations to the *effectiveness* of the approach developed in this study with regard to its ability to influence the relationship between emotional intensity and creativity during idea generation. This however, will be the subject of future research that we will address in more detail in the discussion chapter (section 8.5.2) of this thesis.

8. Discussion

8.1 Introduction

The research presented in this thesis describes the first steps in the development of two novel approaches to interactive systems that influence the emotion-creativity link, that aim to help people to get more out of their own creative capabilities. In this final chapter, we summarize the studies that have been undertaken to answer the research questions and attain the research objectives that we have set in the introduction chapter of this thesis, and thus, the contributions of the work as a whole. Several contributions to creativity science and interactive systems research are claimed, and the limitations that emerged throughout the studies that are relevant to these contributions are discussed. Throughout our studies several potentially interesting limitations to the effectiveness of our developed approaches have been identified. To enable further investigation, and offer possibilities to overcome these potential limitations, we identify and discuss new directions for future work.

8.2 Summary of the studies

We have argued that emotions can influence the way people think and act in a manner that augments or diminishes creativity (section 2.2). Therefore, the ability of people to have the emotions that augment creativity can help them to get more out of their own creative capabilities. We believe that this provides an opportunity for designers of interactive systems that aim to augment creativity, and provides a new application domain for designers of interactive systems that aim to influence emotion (section 2.3.3). How to develop interactive systems such that they can effectively make use of this potential was, until now, an unanswered question (chapters 4, 5, 6, 7). The studies presented in this thesis present some initial answers to this question.

The main challenge that we identified was that the development of an approach to interactive systems that can effectively enable these to influence emotion, should do so in a manner that also suits creativity (section 2.3.3.2). We conjectured, that in order to effectively influence the emotion-creativity link, the way an interactive system causes emotion should be meaningful within the context of the creative task used.

The identified challenges translated into two research questions about whether or not our two new approaches to interactive systems can effectively influence the emotion-creativity link that were supported by two research objectives (one for each study).

RQ1: Can the function of motor expressions in emotion regulation be used to develop an effective approach to interactive systems that influence the emotion-creativity link?

> *O1: Demonstrate that imposing motor expressions can help regulate emotion and augment creativity.*
>
> *O2: Demonstrate that an interactive system can be designed to use the function of motor expressions in emotion regulation to help people perform better on idea generation and insight problem solving tasks that require creativity.*

RQ2: Can the cognitive appraisal processes that form part of positive and negative emotions be used to develop an effective approach to interactive systems that influence the emotion-creativity link?

> *O3: Demonstrate that an interactive system can be designed to use the function of cognitive appraisal processes in positive and negative emotion, to help people perform better on idea generation tasks that require creativity.*
>
> *O4: Demonstrate that an interactive system can be designed to use the function of cognitive appraisal processes in determining the intensity of positive and negative emotion, to influence the degree to which creativity is augmented or diminished.*

This helped inspire and focused the two investigated approaches to interactive systems that aim to effectively influence the emotion-creativity link (sections 5.3, 6.3).

In study 1 (chapter 4) and study 2 (chapter 5) we developed our first approach to interactive systems that influence the emotion-creativity link. This approach was developed to make use of the function of motor expressions in emotion regulation. We focused the capabilities of this approach on the relationship between positive and negative emotions, and creativity during idea generation and verbal insight problem solving. This approach was assumed to be effective, because it does not cause, but rather regulates the emotions that happen during a creative task. Note that there is also evidence from other studies that there can also be a bottom-up, rather than the described top-down effect of motor expressions on the emotion-creativity link (see section 2.2). However, as was explained in detail in section 2.2 we have assumed otherwise. This way, it circumvents the necessity for an interactive system to cause emotions in a manner that is meaningful to the creative task, because the emotions regulated are the emotions that are caused spontaneously by the creative task.

In study 1 we set up a small experiment to demonstrate two different ways in which motor expressions can influence the emotion-creativity link (chapter 4). This, we supposed, would justify using the function of motor expressions in emotion regulation, within an interactive systems context. We demonstrated experimentally that imposing motor expressions that associate with positive emotion and approaching action tendencies, rather than with negative emotions and avoiding action tendencies can augment creativity during idea generation, via an influence on the emotion-creativity link; and, that incompatibility rather than congruence between a motor expression and an emotion can also augment creativity during idea generation (section 4.6). Note that this evidence was preliminary, and not obtained in an interactive systems context. Rather, the study justifies further exploration of motor expressions in an interactive systems context. Thus, the contribution of study 1 is a demonstration of two ways in which imposing motor expressions can help regulate emotion and augment creativity (section 4.7). This suggests that we achieved *research objective O1*.

In study 2 we developed our first approach to interactive systems, which aims to make use of the function of motor expressions in emotion regulation (chapter 5). We developed this approach based on the assumption that positive and negative emotions are caused during a creative task, and motor expression congruence and incongruence can augment or diminish the disposition to have, and intensity of, these caused emotions, which would subsequently influence the emotion-creativity link (section 5.3). To put the developed approach to the test we developed a proof-of-concept interactive system that enables the use of embodied interactions (arm gestures) that are designed based on motor expressions, to record ideas and problem solutions into a microphone (section 5.4). We demonstrated experimentally that these embodied interactions, designed based on motor expressions that associate with positive emotion and approach action tendencies, rather than negative emotions and avoidance action tendencies, augment creativity when used to interact with a machine, via their influence on the emotion-creativity link during idea generation (section 5.6). However, the latter relationship was not found for verbal insight problem solving. Thus, the contribution of study 2 is the demonstration that an interactive system can be designed to use the function of motor expressions in emotion regulation to help people perform better on idea generation tasks that require creativity (section 5.7). This suggests that we achieved, at least partly, *research objective O2*.

Taken together, the contribution of study 1 and study 2 is a novel and effective approach to interactive systems that can be used to hack into the function of motor expressions in emotion regulation, to regulate the emotions that happen during a creative task, in order to influence the emotion-creativity link. We assume that this positively answers *research question RQ1*.

In study 3 (chapter 6) and study 4 (chapter 7) we developed a second approach to interactive systems that aim to influence the emotion-creativity link. This approach was developed to make use of the cognitive appraisal processes that help cause positive and negative emotion, and determine emotional intensity. We focused the capabilities of this approach on the relationship between (the intensity of) positive and negative emotions, and creativity during idea generation. This approach was assumed to be effective, because it manipulates directly the processes that help cause emotions during a creative task. The way the interactive system causes emotion, we assumed, is therefore meaningful within the context of that creative task.

In study 3 we developed our second approach to interactive systems, which aims to hack into cognitive appraisal processes that help cause positive and negative emotion (chapter 6). We developed this approach based on the assumption that appraisals of events in an individual's environment that signal progress toward (goal-conduciveness), rather than away (goal-obstructiveness) from the individual's goals causes positive, rather than negative emotions; and, that a major goal during idea generation is the generation of original rather than unoriginal ideas (section 6.3). To put the developed approach to the test we developed an interactive system that provides believable and real-time feedback about how original a user's ideas are, and can manipulate this feedback to make the user's ideas appear more, or less, original than people typically think these ideas are (section 6.4). We demonstrated experimentally that manipulating computer generated feedback, about the originality of a person's ideas, to be better or worse than people typically expect can cause an intended positive or negative emotion accordingly, and influences creativity during idea generation, via its influence on the emotion-creativity link (section 6.6). Thus, the contribution of study 3 is a demonstration that an interactive system can be designed to use the function of cognitive appraisal processes in positive and negative emotion, to help people perform better on idea generation tasks that require creativity (section 6.7). This suggests that we have achieved *research objective O3*.

In study 4 we reconfigured our second approach to interactive systems, with the aim to hack into the function of cognitive appraisal processes in determining emotional intensity (chapter 7). We developed this approach based on the assumptions that the expectations people have determine in part the intensity of an emotion when it is caused; that the cognitive appraisal processes that help cause emotion also condition people's expectations for similar future events; and that within the context of idea generation the generation of original ideas therefore plays a role in both conditioning expectations, and causing positive and negative emotions, thereby determining the intensity of these positive and negative emotions (section 7.3). To put this conjecture to the test we reconfigured the interactive system that was developed as part of study 3 (section 7.4). We demonstrated experimentally that the manipulation of computer generated feedback, about the originality of a person's ideas to be better or worse than people typically expect can be used to condition the expectations people have about their own ability to generate original ideas, and help determine emotional intensity (section 7.6). A link between emotional intensity and creativity, however, could not be shown in an unequivocal manner. Thus, the contribution of study 4 is simply the demonstration that an interactive system can be designed to use the function of cognitive appraisal processes in determining the intensity of positive and negative emotion in the context of a creative task (section 7.7). This suggests that we have partly achieved *research objective O4*.

Taken together, the contribution of study 3 and study 4 is a novel and effective approach to interactive systems that can be used to hack into the cognitive appraisal processes that cause positive and negative emotion during a creative task, to influence the emotion-creativity link. The influence of this approach to interactive systems on the relationship between emotional intensity and creativity, however, requires further investigation. We assume that this demonstration, at least partly, positively answers *research question RQ2*.

8.3 Contributions

The contribution of the research presented in this thesis as a whole is the development of two novel approaches to interactive systems that are designed to influence the relationship between emotion and creativity with the goal to help people to get more out of their own creative capabilities. In particular, our contribution focused on explicating the mechanisms underlying the two developed approaches within an interactive systems context. We contribute to several research areas in creativity science and interactive systems research. We distinguish between contributions to three related fields within interactive systems research: interactive systems that aim to influence emotion to augment creativity (section 8.3.1), the more general interactive systems that aim to augment creativity (section 8.3.2), and interactive systems that aim to influence emotion (section 8.3.3). Furthermore, we believe that our research contributes to theory about the emotion-creativity link (section 8.3.4). The contributions to these research areas are discussed in the following sections.

8.3.1 Interactive systems that influence emotion to augment creativity

The two developed approaches to interactive systems are a novel contribution to emerging research about interactive systems that aim to influence emotion to augment creativity (section 2.3.3).

Hacking into the function of motor expressions in emotion regulation, to regulate the emotions that are caused during a creative task is a novel approach to interactive systems that aim influence emotion to augment creativity. This is in part because it is the first to explicitly make use of emotion regulation, the ability to modify and control emotions that are caused; and, in part, because it is the first that uses embodied interactions that are designed based on motor expressions as a way of influencing the emotion-creativity link. That is, the few existing approaches attempt to cause, rather than regulate emotion during a creative task (Lench et al., 2011). The way in which such systems attempt to cause emotion is by designing that relate to emotion but not explicitly to a creative task, such as by showing emotional pictures (Lewis et al., 2011), playing emotional music (Morris et al., 2013), or by hijacking social interactions (Nakazato et al., 2014) (section 2.3.3.1). Consequently, embodied interactions have not explicitly been used within that particular context (section 5.2). Thus, a contribution to interactive systems that aim to influence emotion to augment creativity is a novel approach to such interactive systems that makes use of the function of motor expressions in emotion regulation to effectively influence the emotion-creativity link.

Hacking into the cognitive appraisal processes that cause emotion, and determine emotional intensity, during idea generation, is also a novel approach to interactive systems that aim influence emotion to augment creativity. This is, in part, because this approach is the first to explicitly make use of, and manipulate, the cognitive appraisal processes that cause emotion as part of a creative task; and, in part, because it is the first that attempts to take over part of the evaluative aspects of the creative process to find a way into the emotion-creativity link (section 2.3.3.1). That is, the use of emotional pictures (Lewis et al., 2011), emotional music (Morris et al., 2013), and the manipulation of social interactions (Nakazato et al., 2014), as a way to cause emotion, all attempt to cause emotion in a manner that does not relate to the processes that typically cause emotion during a creative task. As a consequence, the focus of our approach on the evaluative aspects of the creative process is the first to make use of these to cause the emotions that happen during a creative task. Moreover, because of the ability of the interactive system to determine emotional intensity, our approach is the first to enable exploration of the relationship between emotional intensity and creativity during idea generation within an interactive systems context (cf. section 2.3.3.1). Thus, another contribution to interactive systems that aim to influence emotion to augment creativity is a second novel approach to such interactive systems. One that makes use of the cognitive appraisal processes that cause emotion and determine emotional intensity during a creative task to effectively influence the emotion-creativity link.

8.3.2 Interactive systems that augment creativity

Our studies also embody a novel contribution to the more general research on interactive systems that aim to augment creativity (section 2.3.2).

Our particular use of embodied interactions as a means influence the emotion-creativity link, is also the first to generally use embodied interactions as a way to augment creativity. That is, interactive systems that aim to augment creativity by unburdening the creative process (section 2.3.2.1), supporting the use of creativity techniques (section 2.3.2.2), or via collaboration with intelligent machines (section 2.3.2.3), do not make use of embodied interactions to achieve their aims. Embodied interactions are different from these typical approaches, because they explicitly make use of the links between the human body and creative thinking. As such our work demonstrates a way in which research about embodiment and creativity can be brought into an interactive systems context. This can extend beyond the design of embodied interactions based on motor expressions, to other links between embodiment and creativity (e.g. Leung et al., 2012; Slepian & Ambady, 2012). Thus, this research also contributes to interactive systems that aim to augment creativity via a novel approach to such interactive systems. One that makes use of embodied interactions that are designed to make use of the links between embodiment and creativity with the goal to augment creative thinking.

The use of the cognitive appraisal processes that cause emotion, and determine emotional intensity, during idea generation, is the first approach to interactive systems that functions by taking over (part of) the evaluative component of idea generation. That is, interactive systems that aim to augment creativity by unburdening the creative process (section 2.3.2.1), or by supporting the use of creativity techniques (section 2.3.2.2), do not aim to take over any aspect of the creative process. Rather, our approach can be seen as a novel form of collaboration with intelligent machines (section 2.3.2.3). Within that context, our approach is novel, because such collaboration typically enables the system to take over part of the generative part of the idea generation process, rather than its evaluative (appraisal) part. As such our work demonstrates a way in which research about the role of evaluation during idea generation can be brought into an interactive systems context. This can extend beyond the focus of our study on originality, into the use of other evaluative processes that form part of a creative process (e.g. Lyer et al., 2009). Thus, another contribution to interactive systems that aim to augment creativity is a novel approach to such systems that takes over (part of) the evaluative component the idea generation process with the goal to augment creativity.

8.3.3 Interactive systems that influence emotion

Furthermore, we believe that our studies are a novel contribution to research on interactive systems that aim to influence emotion (section 2.3.1).

Our use of the function of motor expressions in emotion regulation is the first to demonstrate successfully that embodied interactions, that are designed based on motor expressions, can be used to influence emotion (section 5.3, also see Isbister et al., 2012). That is, emotion induction techniques from psychology (section 2.3.1.1), physiological techniques (section 2.3.1.2), affective mirrors (section 2.3.1.3), and mimicking social interactions (section 2.3.1.4) do not make exclusive use of the function of motor expressions in emotion regulation; and the few interactive systems that do attempt to make use of this function of motor expressions, have only demonstrated an influence on emotion by means of physical positioning systems (Kok & Broekens, 2008), and by means of electrical stimulation (Zariffa et al., 2014), but not via the use of embodied interactions (cf. Isbister et al., 2012) (cf. section 5.2). Thus, one contribution of our research to interactive systems that aim to influence emotion is an approach to such systems that makes use of embodied interactions that are designed based on motor expressions with the goal to influence emotion.

Our use of cognitive appraisal processes, is one of the first to demonstrate that appraisal processes can explicitly be targeted by an interactive system to cause an intended emotion, and is one of the first to demonstrate that such systems can be used to determine emotional intensity. Its novelty is the explicit, rather than the implicit use of cognitive appraisal processes. That is, the use of emotion induction techniques from psychology (section 2.3.1.1), physiological techniques (section 2.3.1.2), affective mirrors (section 2.3.1.3), and mimicking social interactions (section 2.3.1.4), often implicitly, but not explicitly, involve cognitive appraisal processes. For instance, a funny affective mirror might lead to the appraisal that the image is unexpectedly pleasant (cf. Shahid et al., 2013), causing joy accordingly (cf. Scherer, 2009)). It could, however, be argued that interactive systems that explicitly target reward are closely related to our approach (sections 6.2, 7.2), e.g. explicitly rewarding game performance (by scoring points), can cause emotion due to appraisal processes (Järvinen, 2007; Koster, 2012; van Reekum et al., 2004). Explicitly making use of appraisal processes that form part of positive and negative emotions, an in particular outside a gaming context, such as creativity, is novel. Thus, another contribution by our research to interactive systems that aim to influence emotion is an approach to such systems that explicitly makes use of cognitive appraisal processes with the goal to cause emotion and determine emotional intensity.

8.3.4 Theory about the emotion-creativity link

Finally, we argue that our studies offer a novel contribution to theory about the emotion-creativity link (section 2.2), and the relationship between positive emotion and creativity during idea generation in particular (section 2.2.1.1).

Across our four studies we confirmed that positive, rather than negative emotion augments creativity (sections 4.6, 5.6, 6.6). This is a well-established relationship between emotion and creativity (which initially motivated its use in our own studies (section 2.4)), and therefore nothing new (section 2.2.1.1). As such, these findings further support an already large body of work about the relationship between positive emotion and creativity during idea generation (see Baas et al., 2008; Davis, 2009 for meta-reviews). The novel contribution of our studies to theory about this emotion-creativity link, however, is a deepening of the understanding of the link between positive emotions and creativity during idea generation.

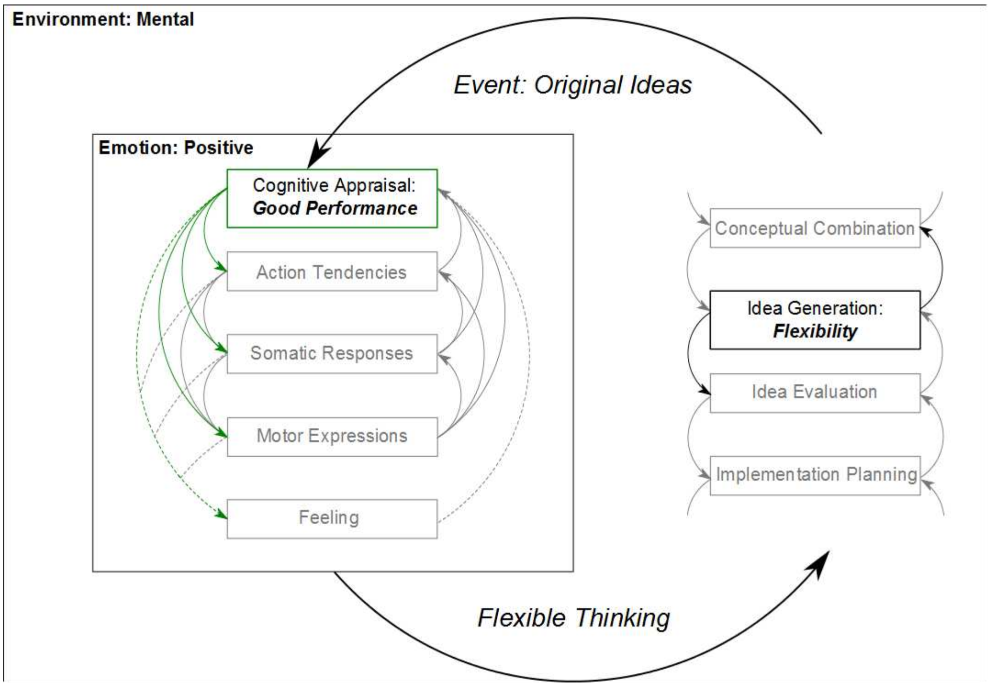

Figure 25 Emerging model of the relationship between positive emotion and creativity during idea generation. Positive emotions influence the likelihood of generating original ideas, by adapting the emotion components in such a way that flexible thinking is promoted (green arrows). The resulting generation of original ideas causes positive emotion in a reciprocal manner.

Throughout our four studies, a working model emerged that describes the relationship between positive emotions and creativity during idea generation (Figure 25). This emerging model was central to the way we developed our approaches to interactive systems (sections 5.3, 6.3, 7.3). This model suggests that positive emotions are caused by the generation of original ideas, and positive emotions change the way people think and act in a manner that increases the likelihood that they will generate original ideas. This contributes to theory about the emotion-creativity link in two ways.

First, our working model is in line with recent work by (Akhbari Chermahini & Hommel, 2012b; Brunyé et al., 2013), who argue that the relationship between positive emotion and creativity during idea generation, is reciprocal. Note however, that no explicit evidence was found for reciprocity, because the experimental designs used in our studies did not permit that (more on this in section 8.4.1).

Second, our findings suggest, for the first time, that the appraisal of the originality, rather than for instance fluency (e.g. section 5.6.1), of an individual's own ideas, causes positive, rather than negative emotion. This is suggested by positive correlations between self-reported positive emotion and originality, rather than fluency (sections 4.6, 5.6.1), and the finding that the manipulation of the appraisal of how original a person's own ideas are, causes positive and negative emotion, and influences creativity during idea generation accordingly (section 6.6). This result is different from recent findings that indicate that fluency (Zenasni & Lubart, 2011) or flexibility (Akhbari Chermahini & Hommel, 2012a; Brunyé et al., 2013) is central to the link between positive emotion and creativity during idea generation.

Thus, the contribution of our four studies, to theory about the emotion-creativity link, is the finding that positive emotions are caused when people appraise their own ideas as original, rather than unoriginal; and that reciprocally, the causation of positive emotion increases the likelihood that people generate ideas that are original, rather than unoriginal. This contribution deepens the understanding of the link between positive emotion and creativity during idea generation.

8.4 Limitations

Throughout the method and study chapters we have discussed limitations of the methods used (chapter 3 and sections 4.5, 5.5, 6.5, 7.5) and the results we obtained with our studies (sections 4.7, 5.7, 6.7, 7.7). The results also suggested that there potentially exist some interesting limitations that might have implications for the *effectiveness* of the developed approaches. In this section, we discuss the main limitations that emerged.

8.4.1 Conception

The way we synthesised a theoretical basis based on previous empirical findings from psychology can also be thought of as a contribution made by our studies (sections 8.3.1). However, because the aim throughout our studies was to test whether our approaches enable the proof-of-concept interactive systems to effectively influence the emotion-creativity link (section 3.2.1), and thus explicate the mechanisms underlying the synthesised approaches, we could not always provide strong evidence for the assumptions underlying the synthesised theory (sections 5.7, 6.7, 7.7). In particular, our developed theoretical basis in all of the studies draws heavily on assumptions about the existence of several reciprocal relationships, which we were not able to test with the experimental designs we chose to use. As a consequence, the studies provide only limited evidence for the assumptions underlying the mechanisms we have attempted to explicate.

First, reciprocity between motor expressions and the other emotion components was assumed to enable emotion regulation (section 5.3). Preliminary evidence was found that motor expressions did not influence emotion directly, but that the effects of motor expressions on emotion were conditional upon the generation of original ideas (sections 5.6.1, 5.6.2). However, because we did not check whether the creative task caused emotion, we could not be sure about whether the interactive system enabled emotion regulation, or whether something else, which we did not measure underlies its influence on the emotion-creativity link (section 5.7).

Second, the assumed reciprocity between the appraised originality of someone's ideas, the emergence of positive emotion, and the subsequent improvement of people's ability to generate original ideas, was central to both developed approaches to interactive systems (sections 5.3, 6.3, 7.3). One could argue that, because the experimental studies showed that the interactive systems had an influence on the emotion-creativity link, this could be construed as preliminary evidence for the mechanisms that form part of the way these systems were conceived (sections 5.6, 6.6). However, we did not set up the experimental studies to test whether this relationship was reciprocal (section 5.5, 6.5), which would require another type of experimental design and quantitative analysis (cf. Kline, 2012; 2013).

Thus, the decision to design our studies to test experimentally the ability of our approaches to interactive systems to influence the emotion-creativity link can only support the way these approaches are conceived in a limited way. The contribution of the latter therefore remains largely theoretical, with only preliminary empirical evidence to support it.

8.4.2 Making

We have also argued that the way our two proof-of-concept interactive systems were made forms part of the contributions claimed (sections 8.3.1, 8.3.2, 8.3.3). However, because these interactive systems have explicitly been made to test our hypotheses, no real consideration was given to how these interactive systems might inspire further development for use in practice (section 3.2.2). As a consequence, the contribution of the way the interactive systems were made, is limited by the restrictions imposed by our methodological choices.

First, our use of embodied interactions successfully enabled testing whether these influence the emotion-creativity link (sections 5.6). However, the embodied interactions used were very specific in their design, and the movements were large and physically demanding (section 5.4.1). This might lead to usability and ergonomic problems, which need to be dealt with if such interactions are to be used in situations other than our experimental studies (section 5.7). Therefore, one could argue that this particular way of making this approach to interactive systems is not scalable to other, more practical, application domains.

Second, our use of feedback manipulation, based on believable and real-time computer generated estimates of originality, also successfully enabled testing whether this influences the emotion-creativity link (section 6.6). However, the way our interactive system was able to estimate originality, was only possible because data from the AUT was already semantically constrained to one subject (brick, paperclip, or knife) (section 6.4.1.2). This allowed us to circumvent a commonly encountered bottleneck in natural language processing technology, namely the inability of such systems to accurately extract meaning from text, the way people can. Therefore, one could argue that this particular way of making this approach to interactive systems is also not scalable to other, more practical, application domains.

Thus, the decision to make our interactive systems in a way that facilitated testing our hypotheses, limits the contribution of the way the systems were made, to the restrictions imposed by our methodological choices. This has implications for its contribution when considered within the context of other, more practical, application domains. Although practical application was obviously not the aim of the made interactive systems, we still feel it is good to mention this, because it delimits more clearly the contribution we claim that the made interactive systems can make.

8.4.3 Experimental evaluation

Central to this thesis's contributions are the results of our experimental studies (sections 8.3.1, 8.3.2, 8.3.3, 8.3.4). These provide evidence for the mechanisms underlying the developed approaches as well as their potential effectiveness. However, the experimental designs used and the manner in which they were executed also introduced several limitations, which we will discuss here.

A first limitation was a trade-off between the required sample size that is necessary to have sufficiently powered studies, the use of the between subject design, and failing to obtain information about individual differences among the participants. That is, in study 1 (section 4.5.1), study 2 (section 5.5.1), and study 4 (section 7.5.1) relatively low sample sizes were used, with a between-subject design. However, we did not assess any individual differences. As a consequence there is uncertainty about whether the found effects of the experimental manipulations on the emotion-creativity link can be (fully) attributed to the designed poses in study 1 (section 4.4.1), the embodied interactions in study 2 (section 5.4.1), and the feedback manipulations in study 4 (section 7.4). With regard to this the following observations can be made:

1. Individuals differ in their sensitivity to emotion-relevant cues from their own body (Andreasson & Dimberg, 2008; Critchley et al., 2004; Ludwick-Rosenthal & Neufeld, 1985; McIntosh, 1996). That is, people may differ in the degree to which they 'listen' to their body and subsequently in the degree to which imposed motor expressions influence their emotions (Critchley et al., 2004). Therefore, a potential uneven distribution with regard to these individual differences may have led to type I errors in study 1 (section 4.7) and study 2 (section 5.7).
2. Individuals also differ in the degree to which they respond emotionally and motivationally to different creative tasks (Akhbari Chermahini & Hommel, 2012b; Soroa et al., 2015). That is, some people may experience idea generation tasks as more pleasant, whereas others may experience these as unpleasant (Soroa et al., 2015). Similarly, some people may feel intrinsically motivated to generate novel ideas, whereas others don't. Here, a potential uneven distribution with regard to these individual differences may have led to type I errors in study 1 (section 4.7), study 2 (section 5.7), and possibly study 3 (section 6.7), and type II errors in study 4 (section 7.7).
3. Individual differences also exist in the degree to which people are sensitive to reward or punishment (Corr, 2008), such as the potential rewarding or punishing effect of the feedback manipulations administered in study 3 and study 4. Given the relatively low sample size in study 4 (section 7.7), and the omission of recording these individual differences there may have been an uneven distribution of such individual differences across the conditions, which may have been a cause of type II errors in study 4 (section 7.7), and possibly type I errors in study 3 (section 6.7).

Thus, the combination of relatively low sample sizes, the use of a between-subject design, and not assessing individual differences introduces uncertainty about whether the study results were due to the experimental manipulations or due to a lack of a uniform distribution of individual differences across the experimental conditions. This in turn threatens the validity of the results in studies 1, 2, and 4 in particular.

A second limitation introduced by the experimental designs used is the lack of a control group in studies 1 (section 4.5), 2 (section 5.5), and 4 (section 7.5). This has consequences for the conclusions that can be drawn about the causality of the mechanisms underlying our approaches to interactive systems.

First, in study 1 (section 4.5) and study 2 (section 5.5) we did not use a neutral pose or embodied interactions. Not using a neutral pose or embodied interaction limits any conclusions that can be drawn about the causal influence of the experimental manipulations on the link between positive and negative emotion and creativity during idea generation (sections 4.7, 5.7). That is, we cannot argue that positive approach gestures or poses enhance positive emotions (congruence) or suppress negative emotions (incongruence), nor that negative avoiding gestures or poses enhance negative emotions (congruence) or suppress positive emotions (incongruence), and thereby influence the link between emotion and creativity accordingly. As such, we cannot conclude that our use of positive approach gestures, or negative avoiding gestures both have had an influence on emotion, and thus not whether congruence or incongruence was responsible for the effects observed. This would have required comparison with the effects of using a neutral arm gesture or pose.

Second, in study 4 (section 7.5) we did not use a neutral feedback manipulation (like we did in study 3, see sections 6.4 and 6.5). Using a neutral feedback manipulation might have provided us with a more fine-grained perspective on the effects of the feedback manipulations on emotional intensity, which could have provided different results and thereby prevented a possible type II error (section 7.7). In particular, a more fine-grained perspective on the effects of varying the feedback manipulations over time could have provided insight into the possible curvilinear relationship between the intensity of positive emotion and creativity during idea generation (Akhbari Chermahini & Hommel, 2012b). If the latter is the case, then not including a control group is a likely cause of our inability to find a clear relationship between positive emotion and creativity. However, not including the neutral condition in such a manner did not allow us this more fine-grained perspective, which limits the conclusions we can draw from the collected data.

Third, the studies all lack a comparison of the experimental manipulations with a control group that would be designed as an absence of a manipulation (sections 4.5, 5.5, 6.5, 7.5). That is, a comparison of the poses and embodied interactions with not posing and not using embodied interactions in the first two studies, and a comparison of the feedback manipulations with not getting feedback in the latter two studies. Omitting this type of comparison means that we cannot justify using the developed approaches compared to say, not using these approaches at all (sections 4.7, 5.7, 6.7, 7.7). As such, we cannot conclude from our studies that it is better to use embodied interactions (or one type of embodied interaction) than not, or that it is better to receive feedback (or a particular feedback manipulation) or none at all. Although we want to emphasise that we did not set out to test this, we believe that it is good to emphasise this particular limitation of the studies presented in this thesis.

Thus, omitting different types of control groups limits any conclusions that can be drawn about the causal processes that form part of the mechanisms of the developed approaches to interactions systems. Moreover, the studies cannot be taken as justification for using the developed approaches.

8.4.4 Materials and measurement instruments

We have also argued that the nature of the relationship between positive and negative emotions, and different steps in the creative process, restricts the materials and measurement instruments in our experimental evaluations (section 3.3). To accommodate these particular restrictions we decided to use the psychometric AUT to gather data about people's ability to generate original ideas, used the objective scoring method to assess creativity, and asked people to self-report their feelings as a proxy to measure emotion (see sections 3.3.1, 3.3.2, 3.3.3 for argumentation). However, each of these methods suffers from several potential threats to (construct) validity. Some of these threats could be addressed (sections 4.5.2, 5.5.2, 6.5.2, 7.5.2), whereas others needed to be accepted. The particular threats to validity that needed to be accepted, thus, introduce uncertainty about the value of the results of our experiments in the contributions claimed.

To gather data based on which creativity can be assessed, we chose to make use of the Alternative Uses Task (AUT) (section 3.3.1). That is, people were asked to list as many diverse and original uses for a common object as they could, within a short time span. Threats to construct validity were addressed, by framing the instructions for the AUT so that the generation of original ideas was emphasized (sections 4.5.2.1). Sensitivity to learning effects became an issue in study 3 (section 6.7), as discussed above (section 8.4.3), as a consequence of the within-subject design (section 6.5). A threat to validity that we needed to accept, was that the motivational aspects of individual creativity, which in part enable creativity (section 2.2.2), could not quite be emulated by the AUT (section 3.3.1). That is, the AUT concerns trivial subjects (e.g. brick, paperclip, knife), which might not motivate people the same way a real-world creative process does, and therefore may yield results that are different from the ones it purports to measure. As a consequence of our decision to use the AUT, it remains, to some extent (Runco & Acar, 2012) unclear to what degree the gathered data really reflects data that could have been generated during a real-world creative process (cf. Amabile, 1982; Zheng et al., 2011).

To assess creativity based on the data gathered with the AUT we made use of the *objective scoring method* (section 3.3.2). That is, we assessed creativity by quantifying fluency (amount of ideas), flexibility (amount of concepts used), and originality (statistical infrequency of ideas). Threats to construct validity were addressed, by using the percentage score (Plucker et al., 2011) to correct the confounding influence of fluency on originality (Silvia et al., 2011), from study 2 onwards (sections 5.5.2.2, 6.5.2.2, 7.5.2.2). Two threats to the validity of this measurement instrument needed to be accepted. That is, the assessment of originality is ambiguous since both original and bizarre ideas are statistically infrequent, which introduces measurement error; and, statistical infrequency correlates negatively with sample size, which introduces inconsistent measures of creativity across the studies (section 3.3.2). From study 3 onwards, our decision to automate the percentage score, introduced an additional source of measurement error (section 6.5.2.2, 7.5.2.2). That is, despite a similar consistency of the automated score, with human scores (section 6.4.1.4), we feel it is unlikely that our interactive system scored originality in a truly human-like way. As a consequence of our ways of using the objective scoring method, uncertainty exists about the degree to which the originality measures used, really measure what they purport to measure (cf. Silvia et al., 2008; 2011; Zheng et al., 2011).

To assess positive and negative emotion we asked people to self-report their feelings (section 3.3.3). That is, we asked them to translate the aspects of the emotion components that they were able to experience consciously, onto a quantifiable medium. Threats to construct validity were addressed, by using Likert scales with emotion words on opposite ends, with which we could best mimic the aspects of an emotion people can subjectively experience (sections 4.5.2.3, 5.5.2.3, 6.5.2.3, 7.5.2.3); by limiting the time between an emotion and the moment of self-report, i.e. the self-report measures were administered right after a creative task (sections 4.5.3, 5.5.3, 6.5.3, 7.5.3); and by explicitly referring to the creative tasks and particular emotional feelings that are of interest to the study, and would be likely to happen during the used creative task (sections 4.5.2.3, 5.5.2.3, 6.5.2.3, 7.5.2.3). In addition, we switched from measuring positive and negative emotion on one scale (sections 4.5.2.3, 5.5.2.3), to measuring positive and negative emotion separately from study 3 onwards (section 6.5.2.3, 7.5.2.3). This enabled us to study the effects of the interactive systems on the link between positive and negative emotion, and creativity, separately. However, as a consequence of these decisions, these self-designed measures have no reference against which we can check their reliability (cf. Gray & Watson, 2007), and introduce inconsistency in the way emotion was measured across the four studies (cf. Shadish et al., 2002).

In addition, our decision to assess only positive and negative emotion and its influence on creativity during idea generation may have yielded results that were confounded by other aspects of the emotion-creativity link that we did not measure (section 3.3.3). In all our studies we assumed that the manipulations used would influence creativity via their influence on either positive of negative emotion (sections 4.5.2.3, 5.5.2.3, 6.5.2.3, 7.5.2.3). However, from our literature we also know that other aspects of emotion (e.g. uncertainty, mixed emotions, arousal, and approach and avoidance action tendencies) (section 2.2). Because we did not measure these we cannot rule out that the effects of the experimental manipulations were confounded, and can therefore (partially) be explained for instance by arousal differences or by differences in action tendencies (sections 4.7, 5.7, 6.7, 7.7).

Thus, on the one hand, our decision to use the AUT with the objective scoring method to assess creativity, and self-report to assess emotion, enabled us to test the relationship between positive and negative emotions and creativity during idea generation; on the other hand, the variation introduced in the measures of emotion and the lack of checks of other potentially confounding factors that can also explain an influence of emotion on creativity also introduced uncertainty about the ability of these measures to accurately assess emotion and creativity, and in particular whether they helped to accurately uncover the mechanisms underlying the way in which our interactive systems influenced the emotion-creativity link. This, in turn, introduces uncertainty about the value of the results of our experimental evaluations in the contributions claimed.

8.4.5 Effectiveness

Finally, we have suggested that an interactive system can effectively influence the emotion-creativity link, when the way it attempts to influence emotion, is meaningful within the context of a creative task (section 2.3.3.2). We can argue that our interactive systems dealt successfully with that challenge, because the obtained results confirmed that they were able to influence creativity via their effects on positive and negative emotion (sections 5.7, 6.7, 7.7). However, some of those results also suggested that there may be interesting limitations to the effectiveness of our two approaches to interactive systems that may limit the way our approaches can be applied.

From our results, two potential limitations to the effectiveness of our use of the function of motor expressions in emotion regulation emerged.

First, our results suggested that motor expressions might be particularly effective when used to regulate positive, but not negative emotions (section 5.7). This can be explained by differences in the degree to which positive and negative emotions are embodied (cf. Dan-Glauser & Gross, 2011). That is, motor expressions might not play a strong regulatory role in negative emotions, but may in positive emotions. Alternatively, this can be explained by differences in the frequency with which positive and negative emotions are caused during a creative task (cf. Akhbari Chermahini & Hommel, 2012a). That is, idea generation might cause positive emotions more frequently than negative emotions. In any case, this limits the effectiveness with which the function of motor expressions can be used to influence different emotions, and subsequently its ability to influence the emotion-creativity link.

Second, our results suggested that using the function of motor expressions in emotion regulation might only be effective for a limited amount of time (section 5.7). This can possibly be explained by habituation (Stepper & Strack, 1993). That is, the repetitive use of the embodied interactions, within a short time span, may lead people to dissociate the interactions from their function in emotion regulation, which reduces the ability of the embodied interactions to regulate the emotions that are caused during the creative task. However, because two different creative tasks were used, and we did not counterbalance the study, differences in the task could also explain these effects. However, if habituation occurs, this will limit the effectiveness with which the function of motor expressions can be used to influence the emotion-creativity link over time.

Our results also suggested several potential limitations to the effectiveness of our use of cognitive appraisal processes.

Generally, our results suggested that the manipulation of cognitive appraisal processes to cause emotion is limited by the appraisals people already have on their own (section 6.7). This can probably be explained by our assumption that the way in which appraisals are manipulated, should not deviate too much from the appraisals people have themselves, which would otherwise render the manipulations ineffective. That is, if the system provides feedback on the originality of an individual's ideas that is too positive or too negative, it is not believable, and yields an unwanted response. The implication of this, is that if a user only generates unoriginal ideas, the interactive system cannot raise the feedback positively to help cause a more positive emotion without jeopardizing the believability of the way the appraisals are manipulated. As such, this limits the effectiveness with which cognitive appraisal processes can be used to influence the emotion-creativity link.

Furthermore, our results suggested two potential limitations to the effectiveness of our use of cognitive appraisal processes to determine emotional intensity, and possibly the relationship between emotional intensity and creativity in general.

First, our results suggested that the manipulation of cognitive appraisal processes to determine emotional intensity is ineffective when used to influence the link between the intensity of negative emotion and creativity during idea generation (section 7.7). This can possibly be explained by the observation that cognitive appraisals most likely did not influence the intensity of negative emotions, via their effects on the expectations people have about their ability to generate original ideas. However, we believe that something else, which we did not measure, explained the influence of the interactive system on creativity. We speculated that particular configurations of the interactive system might have led people to attribute the cause of their more negative feedback externally, e.g. by blaming the interactive system. If this is a common behavioural response, then this limits the effectiveness with which cognitive appraisal processes can be used to influence the link between emotional intensity and creativity in an interactive systems context.

Second, our results suggested that the use of cognitive appraisal processes to determine the intensity of positive emotions is likely to require more precision if it is to effectively influence the link between the intensity of positive emotions and creativity during idea generation (section 7.7). This is because recent findings indicate that the relationship between the intensity of positive emotions and creativity during idea generation is best described by an inverted U-shape (Akhbari Chermahini & Hommel, 2012b). That is, the used configuration enabled the system to cause differences in emotional intensity, however, if intensity is too low or too high, creativity diminishes. Instead, moderate intensities of positive emotion are conducive to creativity. It therefore remains to be seen whether the manipulation of cognitive appraisal processes can be used to target the right amount of intensity of positive emotion, such that creativity is augmented.

Thus, the results of our studies have pointed towards some potentially interesting limitations to the effectiveness with which our two approaches to interactive systems can influence the emotion-creativity link. The limitations suggest several new directions for future work. This, we will discuss in the future work section of this discussion chapter.

8.5 Future work

With the development of and studies about our two approaches to interactive systems, we have taken the first steps toward two novel lines of interactive systems that can help people to get more out of their own creative capabilities. However, the limitations that emerged throughout our studies suggest that further research is required (cf. section 8.4). One good place to start is to address the discussed the potential *limitations to the effectiveness* of our approaches (section 8.4.5). Future work will therefore be discussed that aims to investigate and help overcome these potential limitations.

8.5.1 The effectiveness of hacking into the function of motor expressions in emotion regulation

Based on the results of our studies we have identified two potential limitations to the effectiveness of our use of the function of motor expressions in emotion regulation, to influence the emotion-creativity link. To further investigate these we propose the following two opportunities for future research.

8.5.1.1 Using the function of motor expressions in the regulation of emotions other than positive ones

Our study results suggested that using the function of motor expressions in emotion regulation, was effective for positive, but possibly not for negative emotions (section 5.6). This would limit its ability, to influencing the link between positive emotion and creativity only, rather than to a broader spectrum of possible relationships between emotion and creativity (cf. section 2.2). However, we were not sure whether motor expressions impact the degree of emotion regulation differently for positive and negative emotions, or, whether the creative tasks that we used only caused positive, but not negative emotion, as the latter would simply mean that there were no negative emotions to regulate (section 5.7). To investigate this potential limitation to the effectiveness of our approach, we propose to reproduce study 2 (chapter 5), with the interactive system developed (section 5.4), but replace the creative tasks used (section 5.5.2.1), with a task that causes positive emotion (e.g. an AUT with an easy and fun subject), and a task that causes negative emotion (e.g. an AUT with a difficult and frustrating subject). In addition, a control group should be used so efforts must be made to find out whether it is possible to design embodied interactions that are neutral emotionally speaking (section 5.7). Such a neutral embodied interaction can possibly be uncovered by a pre-study where we observe spontaneously occurring expressions during a creative task (cf. Won et al., 2014). In such a study, the expressions that do not associate with people that display particularly high or low task performance and do not associate with particular positive or negative emotional responding could perhaps provide clues on how to design a more neutral embodied interaction that can be used as a reliable control condition. Furthermore, assessing individual differences and assessing other aspects of emotions than their positivity or negativity can help reduce the potential presence of confounding factors. This way, we can find out whether using the function of motor expressions in emotion regulation, with an interactive system, is limited to the regulation of positive emotions, or whether these apparent limitations are imposed by the emotions caused by the creative tasks that people engage in.

8.5.1.2 Making effective use of the function of motor expressions in emotion regulation over time

Our study results also suggested that habituation might occur with the repeated use of embodied interactions that are designed based on motor expressions (section 5.6). If so, this would mean that there are limitations to the ability of our approach to influence the emotion-creativity link over extended periods of time (section 8.4.5). However, we were not sure whether the differences in effectiveness observed over time, were due to habituation, or due to differences in the creative tasks used, which could explain these differences just as well because we did not counterbalance the tasks used (section 5.7). To investigate this potential limitation to the effectiveness of our approach, we again propose to reproduce study 2 (chapter 5), but with the interactive system (section 5.4) and positive embodied interactions (section 5.4.1), rather than the negative embodied interactions, and a control group that does not use the interactive system; and with three sequential AUTs with different subjects, used in random order, rather than the used AUT and insight problem solving task (section 5.5.2.1). In addition, it could be worthwhile to include individual differences measures to assess whether any possible effects hold for all individuals, or whether they depend on people's ability to 'listen' to their own bodies, or due to individual differences in how people response to idea generation tasks in terms of emotion and motivation (section 5.7). This way, we can investigate whether the effectiveness of the impact of the system's use of embodied interactions designed based on motor expressions, on emotion regulation, declines over time, and therefore determine whether habituation limits the effectiveness of our approach over time.

8.5.2 The effectiveness of hacking into cognitive appraisal processes

Based on the results of our studies we have also identified three potential limitations to the effectiveness of our use of cognitive appraisal processes to cause positive and negative emotions, and in particular to determine emotional intensity, and subsequently the relationship between emotional intensity and creativity during idea generation. To further investigate and possibly to help overcome these limitations, we propose the following three opportunities for future research.

8.5.2.1 Maximising the impact of the way an interactive system can manipulate cognitive appraisal processes

In our studies we observed that manipulating feedback about the originality of an individual's ideas positively could not impact positive emotions when the individual does not generate ideas that are already a little bit original by themselves, without jeopardising the believability of the way the feedback was manipulated (section 6.7). This limits the ability of our approach to help people that have the tendency to generate unoriginal ideas, to generate more original ideas by influencing the link between positive emotion and creativity during idea generation. To overcome this issue, we suspect that the gradual increase and decrease of the degree with which appraisals are manipulated, might be a good starting point. A gradual change, from a pre-determined baseline, can possibly help to raise or lower the expectations people have about their own ability to generate original ideas, which subsequently changes their own appraisals (cf. section 7.2), and thereby the absolute maximum and minimum of the positivity or negativity of the feedback used to manipulate these appraisals. This can possibly enable us to raise the feedback manipulations, despite an initial inability of the user to generate original ideas, without jeopardizing the believability of the way the interactive system manipulates the user's cognitive appraisal processes. Here in particular, individual differences in the sensitivity to rewards may be interesting to take into account as well because the way in which the feedback manipulations should be varied to maximise their impact is likely to differ from person to person (Corr, 2008; Soroa et al., 2015). In addition, assessing more aspects of emotion than its positivity or negativity can help reduce any confounding factors, and can help further explain the mechanisms underlying the influence of feedback manipulation on the emotion creativity-link (section 6.7). We believe that such a study could help maximise the impact of the way the interactive system can manipulate cognitive appraisal processes, and in turn be a first step toward overcoming the described issues.

8.5.2.2 Using cognitive appraisal processes to determine the intensity of emotions other than positive ones

Our studies further indicated that it is possible with this approach to cause negative emotions (section 6.6), but not to effectively determine the intensity of these negative emotions (section 7.6), and we believe that this merits further research. That is, instead of expectations, something else, which we did not measure, could have determined the intensity of negative emotion, and instead of the intensity of negative emotion, something else, which we also did not measure, could have been responsible for the system's influence on creativity. This would limit the applicability of our approach to influencing the link between the intensity of positive emotion and creativity only, rather than a broader spectrum of possible relationships between emotional intensities and creativity (cf. section 2.2). To further investigate this potential limitation, we suggest that an exploratory study is needed to find out more about what specific appraisal processes may determine the influence of the interactive system on the intensity of negative emotion, and whether these appraisal processes can be tied to the creative task or not. Only then, we suspect, will the use of cognitive appraisal processes enable the effective causation of a wider spectrum of emotions, and emotional intensities, which can be used to enable interactive systems to effectively influence the emotion-creativity link.

8.5.2.3 Making effective use of the curvilinear relationship between the intensity of positive emotion and creativity during idea generation

Finally, our results indicated that the configuration of our interactive system used in study 4 (section 7.4), enabled the system to cause differences in the intensity of positive emotions, and subsequently influenced the emotion-creativity link, but did not lead to absolute differences in creativity (section 7.6). This, we argued, could possibly be explained by recent findings that indicate that the relationship between the intensity of positive emotions and creativity, is best described by an inverted U-shape (section 7.7). If this is the case, then the interactive system developed in study 3, was configured wrongly in study 4, and misses the precision necessary to determine the intensity of positive emotion to effectively augment creativity.

As a follow-up study we first propose that the study is replicated by including more experimental conditions (such as variations of the feedback manipulations used that include neutral manipulation as well). This should provide a more fine-grained perspective that could provide a sufficient amount of detail to observe the hypothesised curvilinear relationship between emotion and creativity. In addition, this study should include tests of individual differences to assess how people respond differently to creative idea generation tasks (Soroa et al., 2015) as well as the rewards presented by the interactive system (Corr, 2008). The results of this pre-study can confirm whether there is indeed a curvilinear relationship between the intensity of positive emotion and creativity during idea generation. Moreover, the individual differences assessed can be used to inform the degree to which people are sensitive to the feedback manipulations, and what feedback differences might be most effective for these individuals (section 7.7).

As such the results of the suggested pre-study inform a redesign of the proof-of-concept interactive system used in study 3 and study 4. We suggest that this is done adaptively (cf. Fairclough, 2009), by real-time monitoring of the intensity of any positive emotions that are happening (e.g. by monitoring eye-blink rate (Akhbari Chermahini & Hommel, 2010; 2012b)), which feeds back into the interactive system to inform the degree to which the feedback on the originality of user's ideas should be manipulated. This way, expectations can be conditioned adaptively, which can help the feedback manipulations of the interactive system to converge upon a more precisely determined emotional intensity. We suspect that this will enable the effective use of the curvilinear relationship between the intensity of positive emotion and creativity during idea generation, which can further our work into interactive systems that help people to get more out of their own creative capabilities.

8.6 Conclusion

The contribution of the research presented in this thesis are two novel approaches to interactive systems designed to influence the relationship between emotion and creativity with the goal to help people to get more out of their own creative capabilities. In particular, our studies contribute the mechanisms underlying the developed approaches. As such, the presented research embodies the first steps towards the development of interactive systems that make use of the function of motor expressions in emotion regulation, to help regulate the emotions that augment or diminish creativity. It also embodies the first steps towards the development of interactive systems that make use of the cognitive appraisal processes that cause positive and negative emotions during a creative task, and explores how cognitive appraisal processes can be manipulated to make use of the relationship between emotional intensity and creativity.

Several contributions to the creativity sciences and interactive systems research emerged. That is, the research provides novel contributions to emerging research on interactive systems that aim to influence emotion to augment creativity, the more general interactive systems that augment creativity, interactive systems that influence emotion, and to theory about the relationship between positive emotion and creativity during idea generation.

Despite our efforts to ensure the effectiveness of our system's abilities to influence the emotion-creativity link, a variety of potentially interesting limitations emerged. These limitations relate to the type of emotions our hack of the function of motor expressions in emotion regulation can influence, as well as its ability to effectively keep regulating emotion over time. They also relate to the ability of our hack into cognitive appraisal processes to cause emotion when people are not performing well creatively, and in particular to its ability to target the relationships that might exist between the intensity of different emotions and creativity. We believe that identifying and overcoming these limitations will be essential for the continued development of our two novel approaches to interactive systems. To support this we have presented several lines for future work with this in mind.

As such, it has been, and will continue to be, our ambition to further the development of interactive systems that can influence the emotion-creativity link, to help people to get more out of their own creative capabilities.

The research detailed in this thesis was the first step towards that aim.

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Appendices

Appendix A

de Rooij, A. & Jones, S., 2013. Mood and Creativity: An Appraisal Tendency Perspective. In *Proceedings of the 9th ACM Conference on Creativity & Cognition*. Sydney, 2013. ACM.

Mood and Creativity: An Appraisal Tendency Perspective

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ABSTRACT

There is a strong relationship between the mood one is in, and the way one performs creatively. Previous research has shown that this relationship is complex. In this paper we argue that this complexity partly lies in a faulty conceptualization of mood. We will argue that an appraisal tendency perspective on moods will help to further clarify the relationship between mood and creativity. To support this argument we will highlight some inconsistencies in previous research, and use the appraisal tendency perspective on mood to develop predictions that help explain these inconsistencies and develop new directions for mood-creativity research. Future research is required to assess the accuracy of these predictions.

Author Keywords

Creativity, Mood, Appraisal Tendencies

ACM Classification Keywords

J.4 Social and Behavioral Sciences: Psychology.

General Terms

Theory

INTRODUCTION

At times, creativity seems to flow naturally, while at other times, creativity is effortful, or even blocked. One of the factors that are believed to play an important role in such situations is the mood one is in [1]. Moods are considered to be relatively long lasting, global, and diffuse states, that emerge from the accumulation of emotions and other affective responses over time. Moods function as a temporary disposition to have certain cognitions [15]. These dispositions therefore impact the processes from which creativity emerges. However, empirical findings show many inconsistencies, which suggests that the way in which this happens is complex [1]. This paper discusses how an appraisal tendency perspective on moods can help to further uncover the complexities of the relationship between mood and creativity.

MOOD AND CREATIVITY

Early research on the relationship between mood and creativity focused on general positive and negative moods. The overall pattern of findings was that positive moods are associated with broadened attention, a flexible, inclusive, and heuristic way of processing and generating information, and the motivation to approach difficult tasks [1]. This suits the need to process much and diverse information in early stages of the creative process [cf. 11]. In contrast, negative moods are associated with narrowed attention, strict and systematic information processing and generation, and increased effort investment [1]. This suits the creative need to evaluate and monitor usefulness and appropriateness in later stages of the creative process [cf. 11]. There are however also many contradictory findings. For instance, a positive mood state such as relaxation is shown to impede creative performance compared to a negative mood state such as anger in early stages of the creative process [7]. In turn, anger is associated with relatively unstructured and heuristic processing [2], which is inconsistent with the notion that negative moods overall promote systematic processing. Findings such as these show us that there is more to the relationship between mood and creativity than can be inferred from their positive and negative character alone. This pinpoints the current challenge in research on the relationship between mood and creativity.

One research trend that attempts to deal with this challenge looks at the range of factors that differ between different moods, and how these factors individually impact the processes from which creativity emerges. Within this trend, one line of research explains a mood in terms of its positive and negative tone, as well as the overall level of activation of the sympathetic nervous system. Overall, findings indicate that activation might be a necessary condition for creativity to occur. Here, activation is thought to reflect engagement [1]. Positive moods high in activation (e.g. joy) are associated with increased creative performance during ideation through increased flexibility, whereas activating negative moods (e.g. anger, fear) increases performance during ideation through perseverance. Moods associated with lowered activation (e.g. sadness) do not enhance ideation. A second line of research adds that the regulatory focus that is associated with a mood, i.e. whether a mood induces a focus on promotion or prevention, can further explain the relationship between mood and creativity. Moods with a promotion focus (e.g. joy, anger) tend to benefit ideation through increased flexibility [1]. Those with a prevention focus that are activating (e.g. fear) benefit ideation through increased perseverance, whereas those with a prevention focus that are deactivating (e.g. sadness) are detrimental to ideation [4]. This indicates that a more

C&C '13, Jun 17-20 2013, Sydney, NSW, Australia
ACM 978-1-4503-2150-1/13/06.

detailed perspective on the constituents of moods can further help to explain the relationship between mood and creativity. There are however still contradictory findings. A case in point is that a simple model combining valence, activation and regulatory focus cannot easily explain why a high activation, prevention focus, negative mood state such as anxiety is detrimental to creative ideation [1, 7].

We argue that the way mood-creativity research has conceptualized moods is detrimental to the aim of fully explaining the relationship between mood and creativity. However, we believe that an appraisal tendency perspective on moods, as set out in the literature on mood and cognition [15] can help further explain this relationship. This approach has not yet been explicitly taken in mood-creativity research.

MOODS AS APPRAISAL TENDENCIES

The appraisal tendency perspective on moods states that moods serve as temporary dispositions to have congruent emotions [14]. For instance, people in happy moods are more likely to experience happy emotions, even when the situation only slightly lends itself to it [14].

According to appraisal theory, emotions typically emerge from appraising an event in terms unexpectedness, intrinsic and goal relevance, goal congruence, certainty, urgency, cause (self, other, chance), coping potential, and compatibility with norms and values. There are many more emotion-relevant appraisals, but the aforementioned ones are sufficient to distinguish between common emotion labels such as happiness, anger, and sadness. For instance, one becomes angry when an event is unexpected, goal-relevant, certain, obstructive to goal attainment, caused by a person, and one believes that a desired outcome can be produced, i.e., removal of the obstruction. These appraisals in turn promote an adaptive response, e.g. encountering something intrinsically pleasant promotes incorporation, goal obstruction promotes reactivity, and a sense of power weighs in with the belief that one can produce a desired outcome with the resources at hand. For a review on appraisal profiles for common emotion labels, and the adaptive responses that are promoted by appraisals, see [14].

Empirical findings show that moods are the accumulation of emotions and other affective events (including appraisals), and also serve as dispositions to have congruent emotions. Therefore moods reflect a tendency to appraise situations in a way that is congruent with the emotions and affective events from which they emerge [14]. For instance, an angry mood is characterized by a tendency to appraise events as unexpected, goal-relevant, obstructive to goal attainment, certain, caused by other people, and the belief that a desired outcome can be produced. Empirical findings support this way of conceptualizing moods. For instance, sad moods increase the likelihood that an event is thought to have situational cause, whereas angry moods promote the tendency to think an event is caused by other people [9]. This directs the selection of strategies to deal with a situation. People in a sad and fearful mood have the tendency to appraise situations as uncontrollable, whereas angry and happy moods lead people to think that a situation is controllable, which impacts motivation [10]. Moods characterized by (un)certainty lead people to appraise the outcome of events accordingly, which promotes either a heuristic or systematic processing style [3]. This is in line with the way in which appraisals are known to facilitate emotion [cf. 14]. The appraisal tendency perspective states that it is tendencies such as the above that characterize what we label as particular moods, and mediate the influence of moods on cognition [15]. For further reviews on appraisal tendencies and their effects on cognition, see [10, 15].

In comparison to the dominant conceptualizations of moods used in mood-creativity research, the appraisal tendency perspective implies that the valence of a mood (whether it is positive or negative) cannot be viewed as a unitary construct. Positivity-negativity may arise from a tendency to appraise events as intrinsically (un)pleasant, goal (in)congruent, or (in)compatible with one's normative standards [cf. 14]. Furthermore, activation is moderated by many appraisals, e.g. unexpectedness, goal obstruction, and uncertainty increase activation [13]. Regulatory focus could also be influenced by appraisal tendencies, e.g. intrinsic (un)pleasantness may help promote incorporation or rejection, and coping related tendencies moderate the likelihood that one approaches or avoids a situation on the grounds of ability beliefs. The appraisal tendency perspective shows that these common conceptualizations hold some relation to mood, but it is in the underlying appraisal tendencies that we can learn more about the relationship between moods and human adaptive behaviors.

Given the presented evidence, we believe that the appraisal tendency perspective on moods provides an empirically valid and productive conceptualization of moods, which can be used to further uncover how mood, through its constituents, impacts the processes from which creativity emerges.

MOOD AND CREATIVITY: AN APPRAISAL TENDENCY PERSPECTIVE

The appraisal tendency perspective on the relationship between mood and creativity breaks away from previous approaches that were anchored in the positivity or negativity of a mood, and associated constructs at a fundamental level. Appraisal tendencies provide a detailed empirically validated platform that explains the constituents of moods in a fine-grained manner. We argue that this is essential to the aim of explaining the seemingly complex relationship between mood and creativity, because it is these appraisal tendencies that impact human behavior, and therefore the processes from which creativity emerges. To deliver the first steps of an explanation of the relations between mood and creativity mediated by appraisal tendency theory, and to illustrate its potential, we develop some predictions that can help explain inconsistencies in previous research, and provide some directions for future work. We have divided these predictions along the following themes: 1) Generation and evaluation, 2) engagement, self-motivation, and stress, and 3) direction and content. Note that future research is required to assess the accuracy of these predictions.

Generation and Evaluation

An important theme throughout mood-creativity research is how some moods promote flexible and heuristic thought, which benefits creative performance in early stages of the creative process (e.g. idea generation) whereas others promote systematic thought, which benefits later stages of the creative process (e.g. idea evaluation) [1]. It was argued earlier that the reviewed research could not explain why anxiety impeded idea generation, while in theory, it should benefit creative performance. The appraisal tendency perspective on moods can be used to shed new light on this problem.

According to appraisal theory, anxiety differs from other emotions through the appraisal of events as uncertain [14]. Therefore, moods related to anxiety facilitate a tendency to appraise events as uncertain. Empirical evidence shows that when moods with an uncertainty component are induced, people tend to generate ideas in a systematic manner [3]. Moods characterized by certainty (e.g. happiness, anger) promote less systematic, heuristic approaches [1, 3]. The tendency to appraise the outcome of situations as uncertain or certain therefore moderates the likelihood that one engages in a systematic approach, or relies on heuristics. We therefore predict that moods that are characterized by uncertainty (e.g. anxiety) may therefore benefit later stages of the creative process that require a more systematic approach to information processing.

Flexibility is often opposed to systematic thought. As the above indicates however, being certain does not necessarily promote flexible thought. There is some evidence that appraisals related to goal congruence impact flexibility. The argument is that when an important goal is attained, people relax and become more flexible, which helps finding new goals to pursue, or easily switching to the pursuit of other pending goals, which is also facilitated by flexibility [cf. 14]. Recent findings indicate that flexibility varies among positive moods as a function of goal-directedness [12]. We therefore predict that moods characterized by the tendency to appraise a situation as goal-congruent (e.g. happiness) may increase the likelihood of a flexible approach to creativity, which can benefit creative performance in early stages of the creative process.

Engagement, Self-Motivation, and Stress

A second important theme that arises in mood-creativity research and creativity research in general, is the function of engagement as a requirement for creativity to occur [1]. Current research has linked engagement to activation, which is, as we have tried to show, a problematic construct in mood research. We argue that there is a potential link between two major factors in engagement, namely stress and motivation, within the context of an appraisal tendency perspective on mood and creativity.

Stress occurs when the required adaptation to a situation exceeds or burdens one's ability to cope with that situation. Mild stress levels benefit engagement, too little diminishes it, while too much interferes with cognition overall [6]. The relation between mood and stress is in the interactions between appraisal tendencies that regulate the perception of pressure (e.g. urgency), and appraisal tendencies related to coping. For instance, angry moods promote the tendency to appraise situations as urgent, but at the same time facilitate high perceived control, power, and adaptability to manage that pressure [cf. 14]. Anxiety also promotes a tendency to perceive events as urgent, but is low on perceived power and adaptability, which increases the likelihood that an event exceeds or burdens coping, and increases stress [cf. 14]. We therefore predict that moods such as anger that are characterized by a balance between appraisal tendencies that moderate the taxation of cognition, and appraisal tendencies related to coping potential, are more likely to maintain engagement with a creative activity.

Situations that are self-motivating also benefit creativity though increased engagement with the task at hand [5]. One aspect of self-regulation in motivation that may be particularly susceptible to moods is the belief in one's own ability to produce a desired outcome [5]. Appraisal tendencies related to control and power moderate the belief that a desired outcome can be produced [10]. Moods characterized by the tendency to perceive events as uncontrollable (e.g. sadness, fear) increase the likelihood that one believes that no desirable outcome can be produced. This increases the likelihood that one does not engage in or prematurely disengages with a creative activity. Moods characterized by a tendency to appraise events as controllable (e.g. happiness, anger) increase the likelihood that one believes that a desirable outcome can be produced. This increases the likelihood that one engages in, and remains engaged with a creative activity. We therefore predict that moods characterized by high controllability and power benefit creative engagement.

Direction and Content

An entirely new focus in mood-creativity research could be based on the way appraisal tendencies bias the attribution of a cause and emphasis on particular normative standards. The influence of different moods may thus impact the content and direction of a creative process, and eventually its outcome.

The identification of causes of a situation facilitates the allocation of the appropriate knowledge to deal with a situation [11]. This gives direction to the content of a creative process in an open ended creative situation. When a specific problem is a given, the identification of essential causes determines the quality of a creative outcome [11].

Moods are characterized by a tendency to attribute the cause (e.g. self, other, chance) of a situation in a mood congruent way. For instance, people in angry moods tend to attribute the cause of an event to other people and assume intent [9]. It follows that people in an angry mood tend to retrieve knowledge relating to that other person or group of people, their intentions, and heuristics to deal with that specific situation. Other appraisal tendencies towards causality follow this pattern accordingly [9]. We therefore predict that moods characterized by a tendency to attribute a particular cause, can impact the direction and content of a creative activity.

Direction and content can also depend on the standards applied in evaluative aspects of the creative process, which shape what is deemed relevant or appropriate [11]. There is some evidence for appraisal tendencies that emphasize a particular set of normative standards in different moods [8]. For instance, angry moods emphasize socio-moral concerns relating to justice, rights, and autonomy. For an overview on the relationship between different moods and tendencies toward emphasizing different socio-moral concerns, see [8]. The emphasis put on specific normative standards may bias evaluation of creative ideas, and influence the content of a creative process, and ultimately its outcome. Therefore, we predict that the standards emphasized in different moods influence evaluative modes of thought, which in turn influences the direction and content of a creative activity.

CONCLUSION

Past research shows that the relationship between mood and creativity is complex. A brief but illustrative review has shown that further progress in this field is impeded by the way moods and their constituents have been conceptualized. We have argued that an appraisal tendency perspective on moods provides an empirically valid and productive alternative to previous conceptualizations of mood, with which we can further attempt to uncover the impacts of moods' constituents on the processes from which creativity emerges. To support our arguments we have developed predictions that offer a new perspective on inconsistencies found in previous work, and point towards some new directions for research on the relationship between mood and creativity. Future research is required to assess the accuracy of the developed predictions.

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Appendix B

de Rooij, A. & Jones, S., 2013. Motor Expressions as Creativity Support: Exploring the Potential for Physical Interaction. In *Proceedings of the 27th International British Computer Society Human Computer Interaction Conference*. London, 2013. British Computer Society.

Motor Expressions as Creativity Support: Exploring the Potential for Physical Interaction

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This research explores the effects of physical interactions designed on the basis of motor expressions to support creative ideation in creativity support technologies. The presented research looks into the effects on creative ideation of incompatibility between motor expressions and problem situations, and appraisals of (un)pleasantness. We report the results of a preliminary study which suggests that affective incompatibility between a problem situation and a motor expression benefits creative ideation, and that pleasantness motor expressions enhance task enjoyment, which in turn leads to a beneficial effect on the originality of ideas generated. Based on these results, we conclude with two new directions for the design of physical interactions with novel creativity support technologies.

Affective Computing, Cognitive Appraisal Theory, Creativity Support, Ideation, Embodied Interaction

1. INTRODUCTION

Affect is known to exert a strong influence on creative performance (Baas et al. 2008). This provides an opportunity for the development of interactive technologies that support creativity using affect as a mediator. However, to utilize this link between affect and creativity, we need to develop an interactive technology that can influence affect. We argue that this technology can be developed from the use of motor expressions to design physical interactions for creativity support technologies. It is this opportunity that will be explored in this paper.

Motor expressions are the physical actions that are elicited by an affective process, such as facial expressions, postures, and gestures (Ellgring & Scherer 2007a, 2007b). Performing motor expressions has been shown to influence affect (Price et al. 2012). This could in turn influence creative performance (cf. Friedman & Förster 2002). Interactive technologies increasingly rely on physical interactions, such as gestures and postures, as a direct and natural way to facilitate interaction between man and machine (cf. Isbister 2011). Considering these two observations, motor expressions are an interesting option for the design of physical interactions for novel affective creativity support technologies.

We envision that the integration of motor expressions into physical interactions can offer HCI designers novel tools to develop technologies that can exert an influence on creative performance. For instance, creativity enhancing gestures could be used as a means to record ideas during an idea generation session. This would then benefit creative performance during that idea generation session.

However, before we can move towards such applications it is important to investigate how motor expressions influence creative performance. We have identified two relevant lines of research from the psychological sciences, which link creative performance to the incompatibility between a motor expression and the affective nature of a situation, and to the effects of specific appraisals related to pleasantness. The work reported here experimentally explores these two lines of research with a focus on creative ideation.

In the remainder of this paper, we first provide an overview of the relationship between motor expressions and affect, and then consider the relationships between motor expressions and creativity identified in the above two lines of research. This leads to the development of two hypotheses about the way in which motor expressions can influence creative ideation. In sections 4 and 5 we describe an experiment conducted in order to investigate these hypotheses. Finally, we discuss the implications of our results for the design of physical interactions for novel affective creativity support technologies.

2. MOTOR EXPRESSIONS AND AFFECT

We smile when we are happy, and slump our posture when we are sad. Cognitive appraisal processes, i.e. the processes from which emotions emerge, often elicit motor expressions (Ellgring & Scherer 2007a, 2007b). However, motor expressions themselves provide a context in which new events can be interpreted (for reviews, see Price et al. 2012, Reimann e al. 2012). In other words, motor expressions influence how events are interpreted by eliciting a tendency to appraise events in the same way as the appraisal that elicited (or typically elicits) that motor expression.

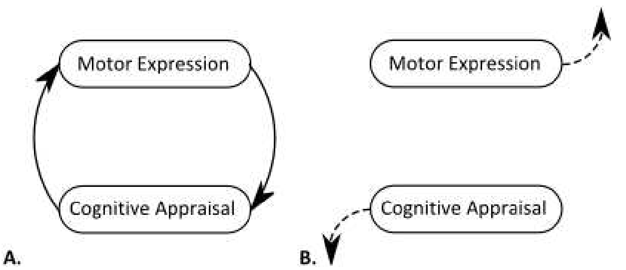

Figure 1: A. Affective coherence, the expressions elicited by an appraisal also help elicit that appraisal. B. Affective incoherence, motor expressions incompatible with the appraisal do not do this.

This reciprocal relationship implies that motor expressions help stabilize an appraisal tendency over time by providing positive feedback to the appraisal that elicited that motor expression (figure 1A). For example, smiling occurs when something pleasant happens, but smiling in turn also positively influences the way we appraise other events. This helps to sustain a pleasant outlook on subsequent events. There is also some empirical evidence to support this. Neumann and Strack (2000) found that pulling a lever towards you increases the speed with which people evaluate positive information, and pushing a lever away from you increases evaluation speed for negative information. However, where there is incompatibility, for example, if you push a lever away from you while evaluating positive information, the speed at which you can evaluate that information is reduced. Centerbar et al. (2008) evidenced that the compatibility, as opposed to the incompatibility, between the affective nature of a story and posed motor expressions (including smiling, frowning, arm flexion and arm extension) benefits recall from short-term memory for affectively congruent information present in that story. Soussignan (2002) found that when people produce a smile while looking at pleasant scenes or funny cartoons, they rate the scenes and cartoons as more pleasant and funnier than when they keep their lips pressed down. The motor expressions in these exemplary works are all typically elicited by appraising an event as pleasant (cf. Ellgring & Scherer 2007a, 2007b) and the evidence provided by these studies shows how motor expressions bias processing towards congruent information. If stabilization occurs and sustains, this is what we typically call affect, and when multiple appraisals stabilize in response to an event, this is what we typically call an emotion (Lewis 1996).

3. MOTOR EXPRESSIONS AND CREATIVITY

Affect has been linked to creative performance in diverse ways (Baas et al. 2008). However, little research is available on the relationship between motor expressions and creativity, as mediated by affect. We have identified two potential lines of research that can help explain this relationship concerning: 1) affective incompatibility, and 2) affective compatibility for specific creativity-relevant appraisals, such as pleasantness.

3.1 Affective incompatibility

If a motor expression is incompatible with an appraisal process, e.g. when we are made to frown while we appraise an event as pleasant, this breaks the positive feedback loop and overall tendency to appraise new events in a congruent way (Figure 1B). This limits the speed with which affective information is processed (Neumann & Strack 2000), and impairs memory recall for affective events (Centerbar et al. 2008). However, this also removes the bias towards an appraisal that is needed to stabilize a particular appraisal (cf. figure 1A), which essentially broadens people's thought processes (cf. figure 1B). In line with this assumption, Huang and Galinsky (2011) found that incompatibility between motor expressions and a variety of affective concepts increase the unusualness of associations in a categorization task. We suspect that this may benefit performance on creative ideation, which typically benefits from the generation of many, and diverse ideas (Isaksen et al. 2011). This leads to our first hypothesis.

Hypothesis 1: Incompatibility between a motor expression and the affective nature of a creative situation benefits performance on creative ideation.

3.2 Pleasantness expressions

Compatibility of a motor expression with an affective event can however also benefit creative ideation, not through the process of reaching stability itself, but by the adaptive effects the stabilization of specific appraisal encourages. We have previously argued that some appraisal processes are responsible for creative performance due to their role in moods and emotions (De Rooij & Jones 2013). It is likely that the same holds for the relationship between appraisal processes and motor expressions. In particular, appraisal processes of intrinsic (un)pleasantness and goal-congruence seem to enhance performance in creative ideation (Baas et al. 2008). These processes are often subsumed under the general appraisal of pleasantness (cf. Scherer 2009). Tendencies to appraise events as pleasant are associated with a more extensive memory search with the adaptive goal to incorporate information. These effects are known to carry over into increased creativity (Fernández-Abascal & Martín Diaz 2013) through increased originality (Friedman & Förster 2002), and under specific embodied conditions into increased cognitive flexibility (Price & Harmon-Jones 2010), the latter two being classic indicators of performance in creative ideation (Guilford 1967). This leads to our second hypothesis.

Hypothesis 2: Motor expressions associated with appraisals of pleasantness benefit performance on creative ideation.

4. EXPERIMENTAL STUDY OF MOTOR EXPRESSIONS AND CREATIVITY

To test the two hypotheses above, we conducted a small experiment. We used a 2 (motor expression: pleasant vs. unpleasant) × 2 (problem situation: pleasant vs. unpleasant) between subjects full factorial design. Dependent variables were fluency, flexibility, and originality as indicators of creative ideation (Guilford 1967), task enjoyment (Akhbari Chermahini & Hommel 2011) and activation (Baas et al. 2008) as potential affective mediators of creative performance, expression effort as a potential external source of variation (cf. Friedman & Förster 2002), and a check for the (un)pleasantness associated with the given problem situations. The experimenter was blind to the conditions.

4.1 Participants

A total of 32 participants (18 females, 14 males) responded to an advertisement offering a bar of chocolate and an interesting learning experience in exchange of 20 minutes of their time. Participants' ages ranged from 23 to 51 with a mean of 32, and a standard deviation of 7.2; the majority of the participants were students and employees of City University London, London, United Kingdom. Participants were randomly assigned to the conditions. Two participants were excluded from the sample for failing to execute the experiment's instructions.

4.2 Procedure

On arrival, participants were seated, handed an overview of the experiment's procedure, and subsequently signed informed consent. Instructions were given for poses that were characteristic of motor expression responses to unpleasant or pleasant events. Unpleasantness was expressed by lowered eye brows, arm extension, and a slightly shrunken and tense posture, and pleasantness was expressed by smiling, arm flexion, and a relaxed and open posture. Participants were asked to keep this pose throughout the experiment. Expressions were modelled after the findings by Ellgring & Scherer (2007a, 2007b) and Friedman & Förster (2002).

Next, participants were handed instructions for an idea generation session. Participants were asked to imagine themselves in a pleasant or an unpleasant problem situation. That is, they were either asked to imagine themselves in a situation where they encountered someone they found attractive, and their goal was to attract that person, or in a situation where they encountered someone they found repulsive, and their goal was to get rid of that person. After the imagination procedure, participants were asked to come up with, and write down, as many ideas as they could in response to the given problem situation within 5 minutes (timed).

Directly following the idea generation session the participants were handed a survey. The (un)pleasantness of the problem situation was rated on a scale of 1, very unpleasant, to 8, very pleasant ("How (un)pleasant do you find the imagined problem situation?"). The effort required to pose the instructed motor expressions was rated on a scale of 1, no effort, to 8, very effortful ("How effortful was it for you to keep your body in the instructed pose?"). Task enjoyment was rated from 1, very unpleasant, to 8, very pleasant ("Did you experience the idea generation task as (un)pleasant?"). Activation level was rated from 1, tired, to 8, lively ("How do you feel right now?"). Following completion of the survey that contained these questions, participants were debriefed and sent on their way.

4.3 Indicators of creative performance

Table 1: Descriptive statistics of creativity related dependent variables including means, standard deviations, and Pearson correlations. * $p < 0.05$, ** $p < 0.01$

		Mean	SD	1	2	3	4	5
1	Originality	1.38	1.15	—				
2	Flexibility	7.37	2.51	.632**	—			
3	Fluency	10.10	3.56	.531**	.714**	—		
4	Enjoyment	4.90	1.60	.418*	.360	.177	—	
5	Activation	3.63	1.22	.155	.181	.200	-.461**	—

We used three classic indicators of performance on creative ideation tasks, i.e., fluency, flexibility, and originality. Fluency was assessed by counting the amount of non-redundant ideas generated by an individual participant (in some cases duplicates were removed). Flexibility was assessed by counting the different semantic categories used by each participant. Originality was assessed by counting the amount of ideas generated by an individual participant that were unique in relation to the sample as a whole (after Guilford 1967).

5. EXPERIMENTAL STUDY RESULTS

Table 1 shows the means and standard deviations, as well as Pearson correlations for the dependent variables relevant to creative performance. Originality correlated with flexibility and fluency, flexibility also correlated with fluency. Task enjoyment correlated with originality, and activation correlated with task enjoyment, showing a negative relationship. Indicators of creative performance did not correlate with activation.

In our setup we assumed that the problem situations people were asked to imagine themselves in would be seen as pleasant or unpleasant. A t-test confirmed this assumption, with the unpleasant situation rated less pleasant ($M = 3.5$, $SD = 1.65$) than the pleasant problem situation ($M = 5.5$, $SD = 2.00$), $t(28) = 3.00$, $p = 0.006$. We also suspected that the two expressions differ in effort, e.g. unpleasantness expressions require a slight increase muscle tension, whereas the pleasantness expression requires taking a comfortable posture. This was confirmed in a t-test, with posing pleasantness expressions ($M = 4.06$, $SD = 1.57$) being less effortful than unpleasantness expressions ($M = 5.57$, $SD = 0.76$), $t(28) = -3.28$, $p = 0.003$. To account for this additional source of variation we included expression effort ratings as a statistical covariant in further analysis.

5.1 Affective incompatibility

We submitted the fluency, flexibility, and originality scores individually to a 2 (motor expression) × 2 (problem situation) ANCOVA. The results show a significant motor expression × problem situation interaction effect for fluency ($F(1, 25) = 7.60$, $p = 0.011$, $\eta_p^2 = 0.23$) and originality ($F(1, 24) = 7.08$, $p = 0.014$, $\eta_p^2 = 0.23$). For flexibility the effect was not significant ($F(1, 25) = 4.01$, $p = 0.056$, $\eta_p^2 = 0.14$) but was large. The interaction effect shows higher means for all indicators of creative performance for experimental conditions where the affective nature of the posed motor expression response was incompatible with the affective nature of the problem situation (figure 1). This supports hypothesis 1.

As expected, the problem situation itself did not significantly impact fluency ($F(1, 25) = 0.23$, $p =$

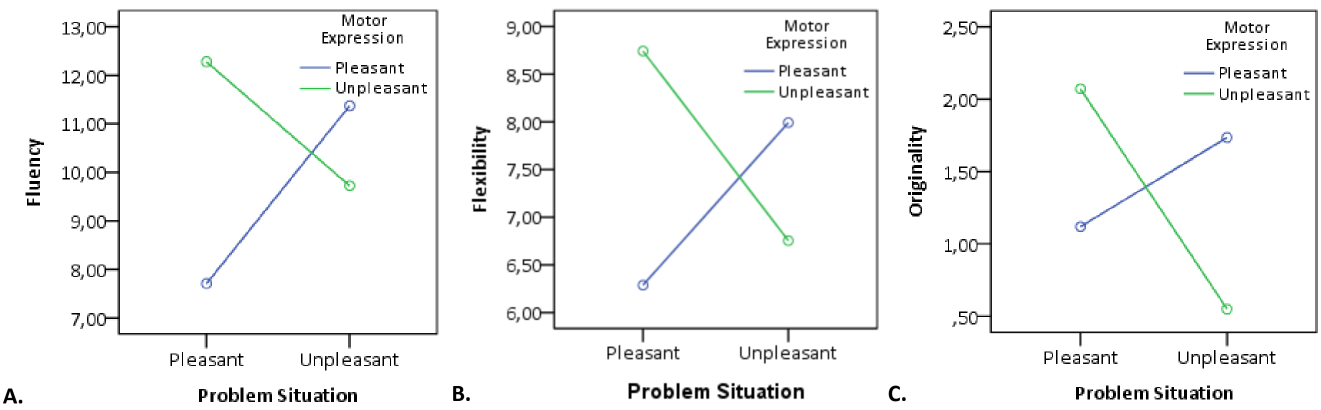

Figure 2: Marginal means for motor expression × problem situation on A) Fluency, B) Flexibility, and C) Originality

0.635, η_p^2 = 0.01), flexibility (Fluency ($F(1, 25)$ = 0.02, p = 0.882, η_p^2 = 0.00), or originality (Fluency ($F(1, 24)$ = 1.19, p = 0.286, η_p^2 = 0.05). More unexpectedly, motor expression did not directly account for any of the variables indicative of creative performance, fluency ($F(1, 25)$ = 1.23, p = 0.277, η_p^2 = 0.05), flexibility ($F(1, 25)$ = 0.32, p = 0.576, η_p^2 = 0.01), and originality ($F(1, 24)$ = 0.61, p = 0.807, η_p^2 = 0.00). The latter does not support hypothesis 2 as a main effect.

5.2 Pleasantness expressions: Mediation of task enjoyment

The descriptive statistics do show a correlation between task enjoyment and originality, and activation and task enjoyment (table 1). This may point towards a more complex relationship between affective processes, motor expression, and creative ideation.

We submitted ratings of task enjoyment and activation level individually to a 2 (motor expression) × 2 (problem situation) ANCOVA. Motor expressions influenced activation level, with unpleasantness expressions (M = 4.29, SD = 1.14) resulting in more self-reported activation than pleasantness expressions (M = 3.06, SD = 1.00), $F(1, 27)$ = 7.39, p = 0.011, η_p^2 = 0.22. Motor expressions influenced task enjoyment, with pleasantness expressions (M = 5.44, SD = 1.63) resulting in more task enjoyment than unpleasantness expressions (M = 4.29, SD = 1.38), $F(1, 25)$ = 4.34, p = 0.048, η_p^2 = 0.15.

To see whether task enjoyment mediated an effect of pleasantness motor expressions on originality, we did a multiple linear regression analysis on originality, with motor expression × problem situation recoded as one variable reflecting (in)compatibility, activation level, and task enjoyment as predictors. The results were fed into a Sobel test to find out whether there was a significant mediation effect. The results show a significant contribution of both affective incompatibility (β = 0.39, $t(28)$ = 2.41, p = 0.024) and task enjoyment (β = 0.55, $t(28)$ = 3.27, p = 0.003) to originality. No significant contribution was found for activation level (β = 0.27, $t(28)$ = 1.50, p = 0.146). The test showed that mediation of task enjoyment of motor expressions' effects on originality is significant (Z = -1.77, p = 0.037). This supports hypothesis 2.

6. DISCUSSION AND FUTURE WORK

6.1 Motor expressions and creative ideation

These results show, for the first time, preliminary evidence that introducing an incompatibility between motor expressions and appraisals of the pleasantness of a problem situation can enhance performance in idea generation. This builds on the work by Huang & Galinsky (2011). The results also show that motor expressions that typically result from a response to something pleasant can help improve originality during creative ideation. This essentially reproduces the results from Friedman & Förster (2002) in a context of varying affective problem situations.

The results also imply that the relationship between motor expressions and creative performance is complex, which highlights an important challenge for the development of motor expressions as creativity support. This is marked by the mediation of task enjoyment for the effects of pleasantness expressions on originality. This mediation cannot be explained in terms of the coherence between a pleasantness expression and a pleasant problem situation. Instead, this mediation was found in both pleasant and unpleasant problem situations. Pleasantness is typically elicited by appraising an event as intrinsically pleasant, or congruent with one's goals. The generation of an idea brings one a step closer to the goals of ideation, i.e., generating many and diverse ideas. Therefore, creative ideation itself typically elicits pleasantness, as long as it is not obstructed in any way (Akhbari Chermahini & Hommel 2011). This introduces compatibility between the affective nature of creative ideation itself and the pleasantness motor expression.

6.2 Directions for the design of physical interactions to support creative ideation

The results point towards two new directions for the design of physical interactions with novel affective creativity support technologies.

If we want to benefit performance in creative ideation through affective incompatibility of motor expressions and problem situations, we can either adapt the physical interaction according to the affective nature of the problem situation, or attempt to influence the interpretation of the problem situation to oppose the physical interaction. The first is problematic from a usability perspective because it would lead to inconsistency in interaction. The second requires an additional system that targets the cognitive process of appraisal directly. For instance, systems that offer a representation of a creative activity that is accessible to the user can be adapted to emphasize the aspects of an activity that match the appraisal process that is targeted. If we want to emphasize pleasantness in this representation, there must be an emphasis on those aspects of the activity that are congruent to the goals set by the creative activity.

A perhaps more immediately promising route to use motor expressions as creativity support is implied by the finding that the process of creative ideation itself is likely to be compatible with pleasantness expressions. This helps stabilize the appraisal processes associated with pleasantness, which is shown to support the originality of responses during creative ideation. Furthermore, we have seen that this result holds under varying conditions of different problem situations. The focus on one set of motor expressions can be used to design physical interactions that are consistent, which benefits usability.

To conclude, our findings imply that the use of motor expressions, such as facial expressions, gesture, and posture, that are associated with responses to something that is appraised as pleasant, can be used to support creative ideation in a relatively robust way. This could allow for the integration of expressions into the interactions we have with novel technologies to guide and enhance creative performance. A major challenge will be to find ways to translate these results into viable HCI technologies. Future research will focus on the integration of gestures based on pleasantness expressions such as the ones used in this study in a physical interaction paradigm to replicate our results within the context of a human-computer interaction setting.

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Appendix C

de Rooij, A., 2014. Toward Emotion Regulation via Physical Interaction. In *Companion volume of the Proceedings of the 19th International Conference on Intelligent User Interfaces*. Haifa, 2014. ACM.

Toward Emotion Regulation via Physical Interaction

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ABSTRACT
Emotions can be regulated to fit a task in order to enhance task performance. Motor expressions can help regulate emotion. This paper briefly reports ongoing work on the design of physical interactions based on motor expressions that can help regulate emotion to fit a task. We argue that to be effective, such interactions must be made meaningful in relation to ongoing appraisal processes, and that such interactions can help regulate emotion via congruence, suppression, or incompatibility. We present previous work on the validation of these arguments within the context of supporting idea generation, and develop a roadmap for research that aims to translate these results to the design of physical interactions under device constraints. The research will enable designers of interactive technology to develop physical interactions that help regulate emotion with the aim to help people get the most out of their own capabilities.

Author Keywords
Affective Computing, Embodied Interaction, Emotion Elicitation, Emotion Regulation, Motor Expression.

ACM Classification Keywords
H.5.2 Information interfaces and presentation: User interfaces - Theory and methods.

INTRODUCTION
Emotion enhances task performance when the adaptive responses promoted by appraisal processes, i.e. the processes that cause emotion [10], fit the performance requirements of a task [2]. For instance, the cognitive flexibility associated with appraising an event as goal-onducive fits well with the performance requirements for idea generation, which typically benefits from generating many and diverse ideas [2]. As such, emotions can be utilized to design technologies that enhance task performance. How to best do this is still an open question.

One approach is to utilize motor expressions of emotion to regulate an emotional response. Psychology shows that motor expressions (gestures, postures, and facial expressions) help regulate appraisal processes [9]. This has been explored within the context of intelligent interaction via 1) anthropomorphic agents that utilize people´s tendency to mimic others´ motor expressions, and 2) the design of physical interactions we have with a technology on the basis of motor expressions [6, 7, 8, 11]. This research focuses on the latter.

The few attempts made to design physical interactions on the basis of motor expressions either report very early stage results [6, 7], or show only partial support for motor expressions as a way to regulate emotion [8, 11]. For instance, interactive furniture designed to support movie experience only influenced positive emotions for positive movie scenes, but not negative emotions [8]. The gist of these projects is that it is challenging to translate the results from psychology to an interactive technology. This translation is the aim of the research presented in this paper.

To this end we review research from psychology to learn about the role of motor expression in emotion regulation. We then discuss previous work that validates our theoretical findings within the context of idea generation, and develop a roadmap for research that aims to translate these results to the design of physical interactions under device constraints. Our aim is to enable the design of novel technologies that regulate emotion to help people get the most out of their own capabilities.

FROM EXPRESSIONS TO EMOTION REGULATION
Psychology shows that there is a reciprocal relationship between emotion-relevant appraisal processes and motor expressions [9, 10]. Appraisal processes typically cause other emotion-relevant processes, and promote specific motor expression responses. Motor expressions in turn help regulate the nature and intensity of the appraisal process, guiding the emergence of an emotional response.

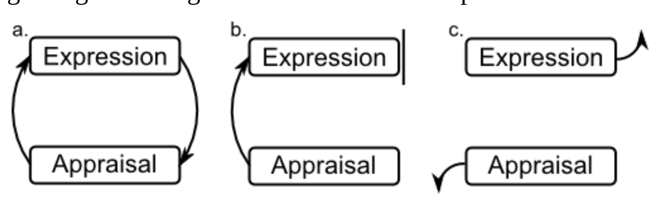

Figure 1. a. Congruence, b. suppression, c. incompatibility - three ways in which motor expressions can regulate emotion.

The structure of the appraisal-expression relationship reveals three ways in which motor expressions regulate

IUI'14 Companion, Feb 24-27, 2014, Haifa, Israel.
ACM 978-1-4503-2729-9/14/02.
http://dx.doi.org/10.1145/2559184.2559186

appraisal processes (Figure 1). First, pairing an appraisal and a congruent motor expression regulates the intensity of that appraisal [9], e.g. smiling intensifies appraisals of pleasantness. Second, suppression of the appraisal process occurs when the expressive muscles associated with an appraisal are restrained [9]. Third, incompatibility between an appraisal and an associated motor expression introduces a feeling of unusualness and a focus on finding a sense of stability, independent of the type of appraisal-expression pairing [5]. These regulatory properties show how motor expressions can regulate emotion.

Motor expressions only help regulate emotion when they can be made meaningful within the context in which the expression occurs [4, 9]. For instance, smiling increases the intensity of pleasantness, but only when something is already appraised as pleasant [9]. This might complicate application. However, many tasks predictably evoke appraisals. For instance, solving difficult problems typically evokes frustration, whereas open-ended idea generation typically evokes pleasantness [1]. Such regularities can be used to pair motor expressions with expected appraisals of a task to regulate the emerging emotion to fit that same task.

FROM EXPRESSIONS TO TASK PERFORMANCE

In principle, a designer can choose a motor expression and an approach to regulate emotion to fit a task (Table 1). For instance, to increase the goal-conduciveness associated with an idea generation task, we can design physical interactions based on the motor expressions associated with goal-conduciveness, using calm movements and decreasing muscle tension.

Appraisal		Adaptive response	Arm expression
Needs	Pleasant	Incorporative thought	Flexing the arm
	Unpleasant	Exclusive thought	Extending the arm Incr. muscle tension
Goals	Conducive	Flexibility	Calm movements Decr. muscle tension
	Obstructive	Narrowness	Instrumental action High muscle tension
Power	High power	High ability beliefs	Agonistic movements Balanced muscle tens.
	Low power	Low ability beliefs	Slow, few, movements Low muscle tension

Table 119. Examples of appraisal processes, associated adaptive responses, and associated arm expressions (after [2, 10]).

As mentioned earlier, a match between the adaptive responses associated with an appraisal process and the performance requirements for a task enhances task performance [2]. For instance, creative idea generation is typically helped by the generation of many and diverse ideas. The cognitive flexibility associated with goal-conduciveness supports this aspect of creative idea generation. Incompatibility promotes an adaptive response of its own, i.e. broadened thinking, because incompatibility promotes a overall reduction of bias [5]. This is also helpful in idea generation. Therefore, physical interactions designed based on motor expressions can regulate emotion to fit the performance requirements of a task, enhancing task performance (cf. Table 1). See [2] for an extensive discussion on this subject.

FROM EXPRESSIONS TO PHYSICAL INTERACTIONS

The design of physical interactions on the basis of motor expressions can be facilitated by the development of new interactive technologies that sufficiently support the use of motor expressions. For instance, myography can be used to sense most relevant properties of an arm gesture, which can in turn be used to ensure that the relevant features of the arm gesture are used as a physical interaction. It is however unknown whether the influence of motor expressions on emotion regulation can translate to the limitations posed by different devices. We identify two major issues below, and in the following section propose directions for future work.

Device constraints can impose limitations on the way motor expressions can be translated to a physical interaction. This can possibly be overcome by scaling the properties of an expression to fit the interactive technology. For instance, performing an arm expression on a 10” tablet device limits the proprioceptive features of the expression, but it may facilitate kinesthetic or muscle force features associated with the expression. If only some aspects of an expression can be sufficiently used, it may still have regulatory properties. Expressions could also influence regulation via a more conceptual link [4]. For instance, arm extensions might regulate unpleasantness. However, at a conceptual level arm extension is about pushing or keeping something away from you. A gesture that just moves to the right can therefore also be constructed as pushing something unpleasant away given the right circumstances. This could in some cases provide another route to integrate motor expressions under device constraints.

PREVIOUS, CURRENT, AND FUTURE WORK

The research done to date is within the application domain of creativity support tools.

A first experimental study (n=32) was designed to assess the viability of emotion regulation via congruence, suppression, and incompatibility to enhance performance on an idea generation task [3]. We tested two hypotheses: 1) posing motor expressions that are typically elicited by pleasantness (smiling, arm flexion) should increase performance on the idea generation task because those motor expressions can be made meaningful as part of the pleasantness of unobstructed thought (congruence) [1], whereas suppression (frowning, arm extension) of these motor expressions decreases performance (suppression), and 2) introducing incompatibility between the emotional nature of the problem situation (having to deal with either a pleasant or unpleasant problem) and the motor expression also enhances creativity through the overall reduction in biased thought associated with incompatibility. The results confirmed our theoretical conjectures. An incompatibility with the appraisal of the problem situation, and the posed motor expressions increased the amount of ideas ($F(1, 25) = 7.60$, $p < 0.05$, $\eta_p^2 = 0.23$) and the originality of the participants' ideas ($F(1, 24) = 7.08$, $p < 0.05$, $\eta_p^2 = 0.23$). Motor expressions associated with pleasantness increased the enjoyment of the idea generation task itself ($F(1, 25) = 4.34$, $p < 0.05$, $\eta_p^2 = 0.15$), which mediated an effect of motor expressions on increased originality ($Z = -1.77$, $p < 0.05$). This shows that motor expression congruence, suppression and incompatibility can be viable ways to regulate emotion with the goal to enhance idea generation.

To translate these results to the design of physical interactions we developed a technology that forms a minimal limitation to the use of arm expressions to interact with an idea generation tool. Acoustic myography is combined with a Kinect sensor to learn the proprioceptive, kinesthetic, and muscle force features of arm expressions associated with (un)pleasantness. These arm expressions are used to control a dictaphone to record ideas as part of an idea generation task. We hypothesize that the recording of ideas can be made meaningful within the context of idea generation because the goal of the idea generation task is extended to recording ideas, as opposed to only generating them. If so, we can expect increased idea generation performance for arm expressions associated with pleasantness. This study is currently running.

Future work focuses on the translation of our previous results to the design of physical interactions under device constraints. We plan to test whether we can scale motor expressions associated with (un)pleasantness to commonly used devices such as 10" tablets. We want to investigate two questions. First, do arm expressions of (un)pleasantness regulate emotion when only parts of the expression can be utilized? This can be investigated by trying to integrate as many aspects of the proprioceptive, kinesthetic and muscle force characteristics associated with motor expressions of (un)pleasantness as possible into the physical movements used to interact with the device. Second, can a conceptual approach to defining motor expressions, where physical interactions are designed to imply (un)pleasantness, be used to regulate emotion? This can be investigated by assessing the regulatory effects of different physical interactions that imply pushing something away from you, or pulling something toward you in the more general sense. Both hypotheses can facilitate a route to integrating motor expressions' capability to regulate emotion in the physical interactions we use to interact with everyday devices.

In summary, the presented research and proposed future work will help designers of interactive technology to develop physical interactions designed on the basis of motor expressions that can help regulate emotion, and via emotion, enhance task performance, with the aim to help people get the most out of their own capabilities.

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Appendix D

de Rooij, A. & Jones, S., 2015. (E)Motion and Creativity: Hacking the Function of Motor Expressions in Emotion Regulation to Augment Creativity. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*. Stanford, CA, 2015. ACM.

(E)Motion and Creativity: Hacking the Function of Motor Expressions in Emotion Regulation to Augment Creativity

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ABSTRACT
Positive emotion can help augment human creativity. To utilize this potential in an interactive system, we propose that such a system should be designed to regulate the emotions that are caused by a creative task. We argue that this can be done by hacking the function of motor expressions in emotion regulation. To this end, we have conceived and made an interactive system that is designed to regulate positive emotion during an idea generation and an insight problem solving task. The system regulates emotion by letting users interact using arm gestures that are designed based on motor expressions, choreographed in a way that enables emotion regulation. Using this interactive system we experimentally test the hypotheses that positive approaching, rather than negative avoiding arm gestures, used to interact with a system, can heighten positive emotion, and augment creativity. The findings demonstrate that an interactive system can be designed to use the function of motor expressions in emotion regulation to help people perform better on certain creative tasks.

Author Keywords
Emotion Regulation; Embodied interaction; Idea generation; Insight Problem Solving; Motor Expressions.

ACM Classification Keywords
H.5.2 Information interfaces and presentation: User interfaces - Theory and methods.

INTRODUCTION
Emotion influences how well and in what way people perform creatively in their everyday lives [2]. This provides an opportunity for designers of technologies that aim to augment creativity to develop systems that influence emotion, and via emotion, augment creativity. However, until now, the possibilities to develop such systems have been limited [20, 21, 23]. This is surprising, because creativity is often seen as the new smart, a sought after skill that helps well-being, innovation, and culture thrive [22].

In this paper, we describe the conception and experimental evaluation of a system that uses embodied interactions based on the characteristics of motor expressions. This system is designed to help regulate positive emotion during two creative tasks: idea generation, and insight problem solving. To interact with the system, people use arm gestures that are designed based on motor expressions associated either with positive emotion and approach action tendencies, or with negative emotion and avoidance action tendencies. These gestures are choreographed in a way that we suppose enables emotion regulation. We demonstrate that using positive approach rather than negative avoidance arm gestures to interact with the system heightens positive emotion, and increases creativity in the tasks used. Thus, the contribution of the research presented in this paper is a demonstration that an interactive system can be designed to use the function of motor expressions in emotion regulation to help people perform better on certain creative tasks.

TEI '15, January 16 - 19 2015, Stanford, CA, USA

http://dx.doi.org/10.1145/2677199.2680552

EMOTION AND CREATIVITY
Emotions have been defined as adaptations in the way people think and act, driven by the changing relationship between an individuals' environment and its well-being [26]. Emotions are made up of changes in a number of components, including the following: subjective evaluations of events in the individual's environment (e.g. this seems pleasant); action tendencies that guide taking appropriate action (e.g. approaching a pleasant event); somatic and neuro-endocrine changes to support these evaluations and actions (e.g. dopamine release in reward structures in the brain); motor expressions - the physical actions that form part of an emotion (e.g. smiling and approach arm movements); and feelings, which are the aspects of these changes that the individual becomes aware of, and are used to monitor emotional wellbeing (e.g. I feel happy) [26].

Creativity has been defined as the development of problem solutions or artifacts that are both novel and effective [22]. This involves executing a distinct set of information processing steps (the creative process). For instance, concepts may be combined to generate ideas, and generated ideas may be evaluated to estimate whether they should be further developed. Creativity is augmented when these steps are executed in a way that favours the emergence of novel and effective outcomes.

The relationship between emotion and creativity depends on the influence of the adaptive nature of an emotion on the execution of the creative process [10]. Positive emotions, and in particular those that are characterized by approach action tendencies favour creativity [2]. Positive emotion (e.g. joy or pride) is generated by the subjective evaluation that an event is conducive to the goals of an individual [26]. This stimulates dopamine release in the mesocortical and mesolimbic areas of the brain, which is associated with an increase in the flexibility with which information is relayed to other brain areas [1]. The resulting increase in flexibility makes it easier to 1) generate many and diverse ideas, a marker for creativity during the idea generation step in the creative process, and 2) gain creative insights as measured by insight problem solving tasks [2] (Figure). Approach action tendencies, or in other words the pursuit of a positive outcome, can further support the link between positive emotion and creativity [2].

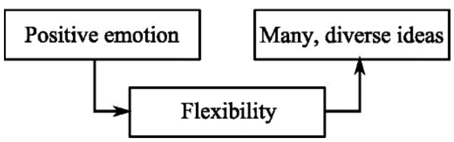

Figure 1. Illustration of the relationship between positive emotion and creative idea generation mediated by flexibility.

Interactive systems designed to influence the relationship between emotion and creativity are scarce, though some examples do exist. Emotion elicitation techniques developed in psychology have been tested on crowd-sourcing platforms within this context [20, 21]. For instance, priming positive emotion by placing a positive picture on the crowdsourcing platform during an idea generation task augments creativity [20]. Another development is using of the tendency of people to mirror each other's facial expressions to influence emotion. For instance, manipulating faces into a desired facial expression in a video feed that is used to communicate during collaborative brainstorming augments idea generation when the faces are manipulated in a positive rather than a negative facial expression [23]. From the examples above, we can see that interactive systems can be designed to influence the relationship between emotion and creativity, to help people perform better on certain creative tasks.

In this paper we focus on the relationship between positive emotion and creativity during idea generation and insight problem solving. This leads to our first hypothesis (H1).

H1: An interactive system that augments positive emotion can augment creativity during idea generation and insight problem solving.

MOTION AND EMOTION

Motor expressions are the physical actions that form part of an emotion [7, 26]. For instance, we smile when we see something nice, or we might push away the things we do not like. Motor expressions also regulate emotion [14]. This is because motor expressions are connected to the other emotion components via feedback loops [26]. Thus, changes in motor expressions influence the disposition towards having certain emotions, and the intensity of those emotions.

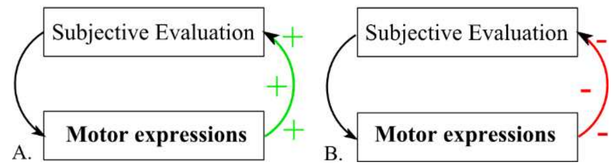

Figure 2. Motor expressions can regulate emotion by introducing A) positive feedback via congruence, and B) negative feedback via suppression.

Congruence between a motor expression and an emotion provides positive feedback to that emotion, which increases the disposition to have and intensity of that emotion (Figure A). This is found across the emotion components, for instance: smiling increases the pleasantness associated with pleasant pictures [27]; arm flexion increases positive feelings when it suggests pulling something towards you that you desire, facilitating approach action tendencies [6]; smiling is shown to activate reward structures in the brain [29]; and mimicking emotion expressions increases the consciously experienced feelings of these emotions [12]. Suppression of a motor expression can lead to negative feedback, which decreases the disposition to have, and the intensity of an emerging emotion (Figure B). For instance, injecting Botox to block frowning reduces symptoms of mild depression [13]. These findings show two ways in which motor expressions can regulate emotion.

There are, however, certain conditions that need to be met for motor expressions to help regulate emotion. We hold the view that emotions are caused by personally relevant events that happen in an individuals' environment [26]. Hence, motor expressions do not 'cause' emotion, but regulate existing emotion. For instance, approach arm movements influence emotion when people subjectively evaluate the emotion of a face, but not when they evaluate its spatial properties [25]. Therefore, we assume that motor expressions need to happen around the same time an emotion is caused. Motor expressions must also fit with an emotion in order to regulate it. For instance, when predicting the cause of future problems and opportunities, adopting an angry or sad pose only influences the prediction of future problems, not opportunities [18]. We assume that these conditions need to be met if we want to use the function of motor expressions in emotion regulation.

Interactive systems designed to use the function of motor expressions in emotion regulation are scarce. One project that uses electrical stimulation of the muscles involved in smiling as a therapeutic tool appears to augment coping [30]. Physical positioning using an automated chair has been used to impose postures that are congruent with movie scenes, which increased the perceived intensity of some positive movie scenes [19]. Embodied interactions have also been designed based on characteristics of motor expressions (postures) that associate with high and low power [16]. Used as a way to interact with a mathematics game, it was hypothesized that this would help to combat math anxiety, but no results on this have been published until now. However, there are reports of heightened emotional engagement in computer games that enable or impose motor expressions during interaction [3, 4, 17]. This demonstrates that it is possible, in certain circumstances, to develop interactive systems that hack the function of motor expressions in emotion regulation.

In this paper we will attempt to enable the regulation of positive emotion by designing arm gestures based on expressions of positive emotion and approach action tendencies, and negative emotion and avoidance action tendencies. This leads to our second hypothesis (H2).

H2: Using positive approach rather than negative avoidance arm gestures to interact with a system augments positive emotion.

EMOTION, MOTION, AND CREATIVITY

Based on the above, we believe that motor expressions may be able to help regulate positive emotion during a creative task because as well as emotion influencing creativity, creativity also causes emotion [2, 5]. In other words, we hypothesize that when a creative task causes emotion, and the motor expression 1) happens at the same time, and 2) fits with the caused emotion, it may be able to help regulate this emotion. For instance, positive emotion can help to generate many, diverse ideas [2] and generating many, diverse ideas can increase the likelihood that a generated idea is an original idea [22] as described above. This in itself can cause positive emotion [5] (Figure). A positive motor expression can then help regulate that positive emotion to the benefit of creativity (Figure 4).

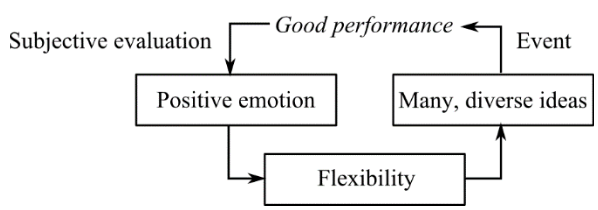

Figure 3. Illustration of the reciprocal nature of the relationship between positive emotion and creative ideation.

This way, motor expressions may influence creativity during idea generation and insight problem solving. In a previous study it has already been shown that smiling and performing arm flexion rather than frowning and performing arm extension helped regulate positive emotion, and via positive emotion, augmented creativity during an idea generation task [11]. In this paper we investigate translation of these findings into an interactive system that hacks the function of motor expressions in emotion regulation to augment creativity, which is novel in an interactive systems context.

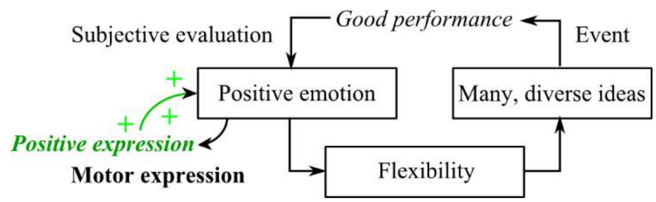

Figure 4. Illustration of how the reciprocal relation between positive emotion and creative ideation can be regulated by positive motor expressions.

We will focus on using arm expressions designed based on motor expressions of positive emotion and approach action tendencies as a means to regulate positive emotion and augment creativity during idea generation and insight problem solving. This leads to our third hypothesis (H3).

H3: Using positive approach rather than negative avoidance arm gestures to interact with a system augments creativity.

HACKING THE FUNCTION OF MOTOR EXPRESSIONS IN EMOTION REGULATION

To demonstrate our ideas we have developed a 'proof of concept' interactive system that: 1) uses arm gestures designed based on motor expressions that associate with positive emotion and approach tendencies, and with negative emotion and avoidance tendencies; and 2) uses a choreography of interaction that meets the conditions that are necessary for motor expressions to help regulate emotion.

Arm gestures

The positive approach arm gesture used to interact with our system is arm flexion (links to approach tendencies [6]) characterized by a centrifugal movement that starts at the side of the body and moves with a curve toward the heart, executed with a balanced level of muscle tension (links to positive emotion [7, 26]) (Figure 11A). This gesture is designed to increase positive emotion, when it occurs, via congruence, and decrease negative emotion via suppression. The negative avoidance arm gesture is arm extension (links to avoidance tendencies [6]) characterized by a centripetal movement that starts at the side of the body, then moves to the chest (diaphragm), and then outwards away from the body, using a slightly increased level of muscle force (links to negative emotion [7, 26]) (Figure 11B). This gesture is designed to increase negative emotion when it happens via congruence, and decrease positive emotion via suppression.

Choreography of interaction

To enable emotion regulation we designed a 'choreography' based on the conditions that enable motor expressions to regulate emotion. The arm gestures need to happen at the same time as any emotions caused during the creative task. We assume that emotions tend to happen right after an idea is generated or an insight problem is answered. These are events at which people might subjectively evaluate their creative task performance (e.g. positive: this idea was very good, or negative: again an idea of insufficient quality). If these caused emotions are positive and involve approach action tendencies, or are negative and involve avoidance action tendencies, the designed arm gestures can help regulate these emotions in an intended direction, and thereby influence creativity (Figure). To implement this, the arm gestures are consistently used immediately after people generate an idea or solve an insight problem.

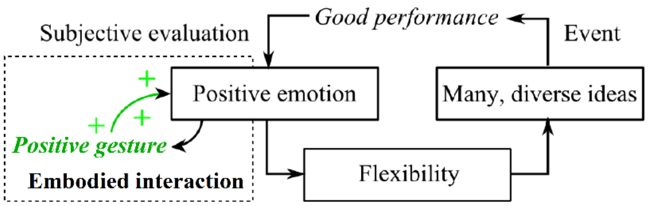

Figure 5. Illustration of how positive approach arm gestures used as part of embodied interaction can help regulate positive emotion due to the reciprocal relationship between creativity and positive emotion.

The interactive system

To test whether the arm gestures used in our proposed choreography of interaction enable us to hack the function of motor expressions in emotion regulation, we developed a basic interactive system for experimental purposes. This system is an application that hosts two creative activities, an idea generation task and an insight problem solving task. The system enables users to record their ideas or solutions with a Dictaphone by using the arm gestures.

The arm gestures are used to record an idea or solution just after it is generated, using a microphone. To start recording, the user does the arm gesture; to keep recording, the user keeps the end position of the gesture stable; and to stop recording the user releases the gesture. For the insight problem solving task releasing the arm gesture would also present the next insight problem. To meet the basic demands of the creativity tasks we present an image of the subject of the idea generation during the idea generation task, and the insight problems that need to be solved during the insight problem solving task on the screen. In case the arm gesture is used to record an idea, visual feedback is given by means of a blinking recording sign (• rec).

To enable the system to automatically trigger the recording, we use a Kinect sensor and a mechanical myograph in a classification setup. We capture the relative angles between the shoulder and the elbow, and the elbow and the wrist of the dominant arm with the Kinect; and muscle force from the biceps, triceps, flexor capri, and extensor capri is calculated by taking the root mean square of the signal of a mechanical myograph (Figure 11). We assume this captures the characteristics on which basis the gestures were designed, see [9] for further details. We trained four hidden Markov models to classify: no gesture; the start of the gesture; keeping the gesture; and releasing the gesture, using the Viterbi algorithm. The parameters were set using grid search. The user and researcher work together to record and annotate the data for the models. Classification is done using ARGMAX of a sequence on the log probability under each model. The developed models are automatically tested for performance. In case of insufficient performance (f_1-score<0.95) the researcher switches to a Wizard of Oz approach, i.e. the researcher triggers the recording him or herself when the user does the arm gesture.

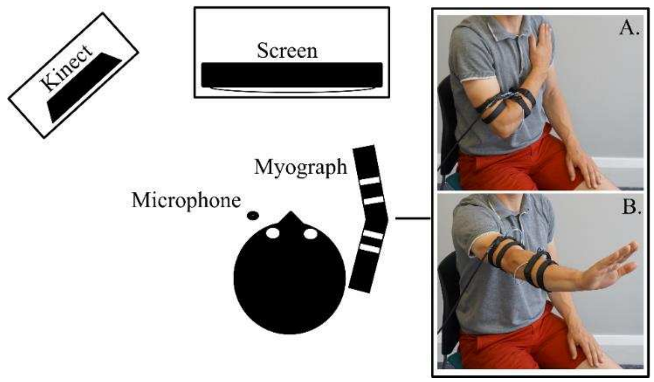

Figure 6. Illustration of the setup (left), and the end position of the A) positive approach and B) negative avoidance gesture.

METHOD

To evaluate the system, we used an experimental between-group setup with people in one group using the positive approach arm gesture, and people in the other group the negative avoidance arm gesture, to interact with the system. We favoured the between group over a within group setup because it enabled us, given limited resources, to test the interactive system with two different creativity tasks. Moreover, we chose to not counterbalance the order of the creative tasks because we prioritized results for the idea generation task, which builds upon our previous work [11], over the insight problem solving task, which we consider more of an exploration. In total 37 people participated in this study (M_{age}=32, SD_{age}=7, Males=20, Females=17, Left handed=7, Right handed=30), with 19 participants using a positive approach and 18 participants using the negative avoidance arm gesture. We switched to a Wizard of Oz mode with 8 participants in both experimental conditions. The participants were students and employees of City University London.

Creative tasks

As mentioned, we embedded two creative tasks in our application. Task 1 was the alternative uses task which was used to assess creativity during idea generation [24]. We instructed participants to generate as many and diverse original uses for a brick. They were given 5 minutes to do this. Task 2 was a verbal insight problem solving task which was used as an indicator of general creative problem solving ability [8]. We instructed participants to solve as many insight problems as they could within 10 minutes, but to try not to spend more than half a minute on each problem. Insight problems are verbal puzzles that have only one correct answer, but cannot easily be solved using the details provided in descriptions of the problems themselves, nor by step-by-step logical thinking (e.g. Q: Is it legal for a man to marry his widow's sister? A: No, he's dead.). For both tasks the participants were instructed to do their best.

Assessment of creativity

To assess creativity during idea generation, we analyzed the outcomes of the alternative uses task by counting the amount of ideas that a participant generated (fluency), the amount of semantic concepts used in the generated ideas (flexibility), and the statistical infrequency of the participants' ideas, given the ideas generated by all the participants [24]. To correct for inflation of originality for participants that were very fluent we used the percentage score, i.e. divided fluency by the count of original ideas [24]. To assess creativity during the insight problem solving task we calculated the percentage of correctly solved insight problems by dividing the amount of answered problems by the amount of correctly answered problems [8, 24].

Assessment of emotion

People self-reported their emotional state on a Likert scale (9 points) from negative to positive emotion after each task, which was part of a questionnaire.

Assessment of possible alternative causes

The questionnaire was further used to assess any possible alternative causes of variation by the designed arm gestures. To this end we asked people to self-report on the: 1) pleasantness and unpleasantness of the arm gestures themselves, 2) physical effort needed to perform the arm gestures, and 3) degree of freedom with which the arm could be moved given that there were four sensor units strapped to their arm, all by using Likert scales (9 points).

Procedure

Upon arrival, each participant was introduced to the study after which informed consent was signed. We strapped the myograph sensors to the participants' dominant arm, and calibrated the Kinect sensor. When the sensors worked correctly, the participants were given instructions to use either the positive approach or the negative avoidance arm gesture as an embodied interaction throughout the study. These were given by example by the researcher. After this, we were ready to start the recording of the arm gestures to train the arm recognition capabilities of the system. In case this did not lead to sufficient classification accuracy, we switched to a 'Wizard of Oz' approach before the two creativity tasks started. After this, we were ready to start the application for the alternative uses task (task 1) after which participants filled in a questionnaire. Then, participants used the application to perform the insight problem solving task (task 2), after which they again filled in a questionnaire. The participants were offered an opportunity to share their thoughts about the study, after which they received a £10 voucher for a large online retailer.

EXPERIMENTAL RESULTS

We first checked for possible alternate causes that could explain variation caused by the arm gestures by submitting them individually as dependent variables (DV) to a one-way ANOVA, with the arm gestures as the independent variable (IV). The results showed no significant differences between the pleasantness or unpleasantness of the arm gestures themselves ($F(1, 35)=0.38$, $p=.545$), the physical effort needed to do the arm gestures ($F(1, 35)=0.03$, $p=.866$) and the freedom with which the arm could be moved ($F(1, 35)=0.226$, $p=.638$). We will therefore not include these in further analysis.

Task 1: Idea generation

To test whether the interactive system augmented positive emotion and creativity during idea generation (H1), we correlated the assessed creativity variables fluency, flexibility, and originality, and emotion. The results show that there was a positive relationship between positive emotion and creativity during idea generation (Table 1). This relationship was characterized by no significant relationship between fluency and emotion, but rather by a significant positive relation between flexibility and positive emotion as well as originality and positive emotion. Higher positive emotion therefore related to higher flexibility and originality. This result supports H1.

	1.	2.	3.	4.
1. Fluency	-			
2. Flexibility	.739**	-		
3. Originality	.500**	.684**	-	
4. Emotion	.314	.493**	.574**	-

Table 1: Correlation between fluency, flexibility, originality, and self-reported emotion. ** is p<.005.

To test whether using positive approach rather than negative avoidance arm gestures to interact with the system augmented positive emotion during the idea generation task (H2), we submitted the assessed emotions as a DV to a one-way ANOVA with the arm gestures as the IV. The results showed that the participants who used a positive approach arm gesture rather than a negative avoidance arm gesture as a means of interaction, self-reported heightened positive emotion after the idea generation task (Table 2) in a way that is unlikely to be random ($F(1, 34)=5.97$, $p=.020$, $\eta^2=.153$). This supports H2.

DV \ IV	Positive appr.		Negative avoid.	
	Mean	**SD**	**Mean**	**SD**
Fluency	17.32	4.85	13.18	6.55
Flexibility	10.95	3.01	7.00	3.41
Originality	0.24	0.08	0.08	0.10
Emotion	6.89	1.24	5.81	1.34

Table 2: Means and standard deviations (SD) for the creativity and emotions assessments (DV) according to arm gesture (IV).

To test whether using positive approach rather than negative avoidance arm gestures to interact with the system augmented creativity during the idea generation task (H3), we used the same statistical approach, but with fluency, flexibility, and originality as the DVs. The results showed that participants using a positive approach rather than a negative avoidance arm gesture performed better creatively (Table 3), a result that was unlikely to be random, for fluency ($F(1, 34)=4.71$, $p=.045$, $\eta^2=.122$), flexibility ($F(1, 34)=13.62$, $p=.001$, $\eta^2=.286$), and originality ($F(1, 34)=25.52$, $p<.001$, $\eta^2=.430$). This supports H3.

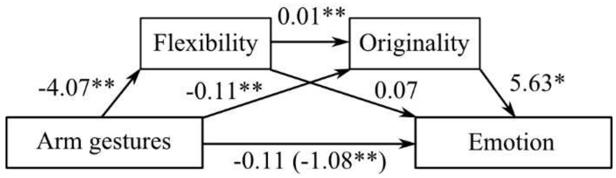

Figure 7. Conditional process model of the arm gestures, flexibility, originality, and emotion. * is p<.05, ** is p<.005.

To further explore the relationship between the arm gestures, emotion, and creativity, we performed conditional process analysis using the bootstrapping method [15]. Conditional process analysis is a non-parametric test that can be used to uncover the process or mechanisms that underlie an observed finding between an IV and DV, via other DVs (mediators). Note that the test cannot be used to test for causality between the mediators and the DV. We used this test with the arm gesture as the IV, flexibility and originality as the mediators, and emotion as the DV (**Error! Reference source not found.**). Fluency was not included because we did not find a correlation with emotion (Table 5). The results showed no significant direct relationship between the arm gestures and emotion, i.e. the bounds of the confidence interval cross zero (B=0.11, 95% CI[-1.04 1.26]). Instead, the results show that the creativity parameters are conditional to the influence of the arm gestures on emotion. This conditional relationship with the arm gestures is characterized by a positive relationship between originality and emotion (B=-0.60, 95% CI[-1.51 -0.12]), and a positive relationship between flexibility, originality, and emotion (B=-0.28, 95% CI[-1.07 -0.06]), that is, the bounds of the confidence interval did not cross zero. Results for a possible relationship of the arm gestures with flexibility and emotion, without originality was not significant (B=-0.28, 95% CI[-1.26 0.17]). This provides preliminary evidence that positive approach rather than negative avoidance arm gestures help regulate positive emotion, when emotion is caused by the generation of original ideas. This supports the assumed process underlying our hypotheses (Figure).

Task 2: Insight problem solving

Before task 2 could be analyzed we checked whether the influence on emotion in task 1 carried over into the results of task 2. Results of a correlation showed no significant relationship between the emotions after task 1 and the percentage of correct answers ($r(1, 35)=.064$, $p=.715$). There were however, clues that emotion after task 1 carried over into task 2 ($r(1, 35)=.307$, $p=.073$). To address this issue we recoded the difference between the emotions after task 1 and after task 2 into a new variable for use in further analysis, to which we refer as emotion′, which represents the change in emotion that was observed.

To test whether the interactive system augmented positive emotion and creativity during the insight problem solving task (H1), we correlated the percentage of correct answers with emotion, and emotion′. Participants on average answered 15.47 insight problems (SD=6.94). The results showed no significant relationship between the correct answers and emotion ($r(1, 35)=.076$, $p=.659$), but did show a significant positive relationship between correct answers and emotion′ ($r(1, 35)=.335$, $p=.046$). A change toward more positive emotion relates to increased percentages of correctly answered insight problems. This supports H1.

IV / DV	**Positive appr.**		**Negative avoid.**	
	Mean	**SD**	**Mean**	**SD**
Correct (%)	0.44	0.19	0.33	0.17
Emotion	6.25	1.52	5.81	1.64
Emotion′	1.45	3.69	1.31	2.98

Table 3: Means and standard deviations (SD) for the creativity and emotion assessments (DV) according to arm gesture (IV).

To test whether using positive approach rather than negative avoidance arm gestures to interact with the system augmented positive emotion during the insight problem solving task (H2), we submitted the assessed emotions and emotion′ individually as a DV to a one-way ANOVA with the arm gestures as the IV. The results showed no significant effect of the arm gestures on emotion after task 2 ($F(1, 35)=0.69$, $p=.413$) or on the recoded emotion′ ($F(1, 35)=0.12$, $p=.731$) (Table 3). This does not support H2.

To test whether using positive approach rather than negative avoidance arm gestures to interact with the system augmented creativity during the insight problem solving task (H3), we again used the same statistical approach, but with the percentage of correct answers as a DV. The results showed that positive approach rather than negative avoidance arm gestures increased the percentage of correctly answered insight problems (Table 3), in a way that is unlikely to be random ($F(1, 35)=5.09$, $p=.030$, $\eta^2=.127$). Positive approach rather than negative avoidance arm gestures increased the percentage of correctly solved insight problems. This supports H3.

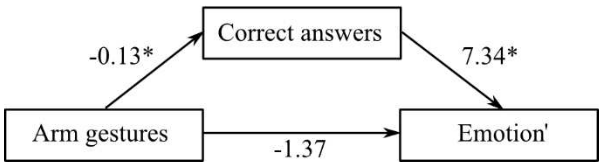

Figure 8. Conditional process model of the arm gestures, percentage of correct answers, and emotion′. * is p<.05.

Given that there was no direct relation between the arm gestures and emotion or emotion′, but there was between the arm gestures and the percentage of correct answers, and between correct answers and emotion′, it may be the case that the relationship between arm gestures, correct answers, and emotion′ follows a similar conditional process as we found in task 1. To test this we used the same statistical approach, but with the percentage of correctly answers as the mediator, and emotion′ as the DV (**Error! Reference source not found.**). The results showed no direct relationship between the arm gestures and the emotion′, i.e. the bounds of the confidence interval crossed zero (B=-1.37, 95% CI[-3.67 0.93]). Instead, it showed a significant relation where the percentage of correct answers is conditional for positive rather than negative avoidance arm gestures to heighten positive emotion, i.e. the bounds of the confidence interval did not cross zero (B=0.98, 95% CI[0.07 2.41]). This provides preliminary evidence that positive approach rather than negative avoidance arm gestures help regulate positive emotion, when emotion is caused by solving insight problems. This supports the assumed process underlying our hypotheses (cf. Figure).

DISCUSSION AND CONCLUSION

Our findings demonstrate that an interactive system can be designed to hack the function of motor expressions in emotion regulation to help people perform better on certain creative tasks. Our findings show that when our interactive system augments positive emotion it also augments creativity (H1). This in itself is nothing new, but it validates this study within the context of previous research on the relationship between emotion and creativity. Our findings also show that when positive approach rather than negative avoidance arm gestures are used, positive emotion is augmented (H2). This finding is a novel contribution to research that aims to use embodied interaction designed based on characteristics of motor expressions to help regulate emotion [cf. 3, 4, 16, 17, 19, 30]. Finally, our findings show that using positive approach rather than negative avoidance arm gestures augments creativity during an idea generation task and an insight problem solving task (H3). This finding is a novel contribution to research that aims to develop interactive systems that influence emotion with the goal to augment creativity, as it provides a novel, embodied, approach to attain that goal [cf. 20, 21, 23]. As such, this research provides opportunities for new technologies that draw on embodied interaction to help regulate emotion, including possible applications such as such as gaming and entertainment [3, 4, 17, 19], education [16], and therapeutic technologies [30], as well as creativity support tools [20, 21, 23].

Moreover, our further exploration of the data provides preliminary evidence for a process that underlies our approach. This is indicated by the finding that there is no direct relationship between the arm gestures and emotion, but that this is dependent on an increase in originality during the idea generation task, and insight problem solving performance during the insight problem solving task. This appears to match with our ideas about the role of the arm gestures in the relationship between emotion and creativity, which is the assumption that for the arm gestures to have an influence on emotion, an emotion must be generated, and this emotion is generated when the user believes that he or she is doing well (Figure).

Interpretation of the results needs to be limited to the context of use in our interactive system, and the conditions posed by our experimental setup. However, the results also point toward interesting limitations in the possible utility of our approach. Whereas during idea generation the results were clear, during insight problem solving there were less pronounced relationships between the arm gestures, emotion, and creativity. Considering that the change in emotion was also characterized by relatively large standard deviations, it might be that other factors, which we did not measure, had a stronger influence on emotion during insight problem solving. However, another explanation could be that the used arm gestures are only effective for a limited amount of time due to habituation [cf. 28]. We cannot rule out the latter because we did not randomize task order.

The results also reveal a possible limitation in the effectiveness of our approach. People who used positive approach arm gestures reported more positive emotion than the people who used the negative avoidance arm gestures, but the latter people were still positive on average. It could well be that the used creative activities did not generate sufficient negative emotion for the arm gestures to help regulate these emotions, and all that we found was that positive approach arm gestures increase positive emotion, and negative avoidance arm gestures suppress positive emotion. Therefore we cannot know from these results whether the function of motor expressions in emotion regulation can be hacked for emotions other than positive ones. Previous attempts at hacking the function of motor expressions in emotion regulation suffered from similar complications [19, 30].

We believe that the latter can be investigated further by pairing embodied interactions designed based on motor expressions, with novel techniques that cause emotion. This will be addressed in future research.

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Appendix E

de Rooij, A., Corr, P., & Jones, S., 2015. Emotion and Creativity: Hacking into Cognitive Appraisal Processes to Augment Creative Ideation. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition*. Glasgow, 2015. ACM.

Emotion and Creativity: Hacking into Cognitive Appraisal Processes to Augment Creative Ideation

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ABSTRACT

Creativity thrives when people experience positive emotions. How to design an interactive system that can effectively make use of this potential is, however, still an unanswered question. In this paper, we propose one approach to this problem that relies on hacking into the cognitive appraisal processes that form part of positive emotions. To demonstrate our approach we have conceived, made, and evaluated a novel interactive system that influences an individual's appraisals of their own idea generation processes by providing real-time and believable feedback about the originality of their ideas. The system can be used to manipulate this feedback to make the user's ideas appear more or less original. This has enabled us to test experimentally the hypothesis that providing more positive feedback, rather than neutral, or more negative feedback than the user is expecting, causes more positive emotion, which in turn causes more creativity during idea generation. The findings demonstrate that an interactive system can be designed to use the function of cognitive appraisal processes in positive emotion to help people to get more out of their own creative capabilities.

Author Keywords

Affective Computing; Cognitive Appraisal; Creativity; Creativity Support Tools; Emotion; Idea Evaluation; Idea Generation; Interactive Systems; Natural Language Processing; Positive Computing.

ACM Classification Keywords

H.5.2 Information interfaces and presentation: User interface; J.4 Social and Behavioral Sciences: Psychology.

C&C '15, June 22 - 25, 2015, Glasgow, United Kingdom
© 2015 ACM. ISBN 978-1-4503-3598-0/15/06…$15.00
DOI: http://dx.doi.org/10.1145/2757226.2757227

INTRODUCTION

Positive emotions can help adapt the way people think and act such that creativity during idea generation is augmented [3]. Interactive systems that aim to influence emotion can, therefore, be designed to help people to get more out of their own creative capabilities. However, not many approaches exist that have successfully targeted this relationship between emotion and creative ideation [9]. The rarity of such systems is surprising because creativity is often heralded as a unique and valuable human skill, one that is at the heart of wellbeing, innovation, and culture [8, 28].

In this paper, we describe the conception, making, and experimental evaluation of an interactive system that is designed to hack into the cognitive appraisal processes that form part of positive emotions, with the goal to augment creative ideation. Based on experimental and theoretical findings from psychology [3, 32, 35], and our own previous studies [9, 11], we argue that the degree to which ideas generated are appraised as original causes positive and negative emotion over time, and that this can influence creative ideation.

On the basis of this argument, we created an interactive system, which autonomously estimates the originality of the user's ideas, and presents these estimates as feedback to the user. This system is designed to be able to manipulate this feedback in a way that conveys that the user's ideas are less original, the same, or more original than people might typically expect, so that we are able to vary the likelihood that people appraise their own ideas as more or less original, and cause positive and negative emotion accordingly.

We hypothesize and experimentally demonstrate that our interactive system can influence the way users appraise the originality of their own ideas, and that making the ideas look more original than they are causes more positive emotion, which augments creativity during idea generation tasks. Thus, the contribution of the research presented in this paper is a demonstration that an interactive system can be designed to use the function of cognitive appraisal processes in positive emotion, to help people perform better on idea generation tasks that require creativity.

EMOTION AND CREATIVITY

Emotions are responses to events that help adapt the way we think and act in support of our own and other's wellbeing [26, 32, 35]. Emotions consist of adaptive changes in a number of components, including: the appraisal of events (e.g. this is appealing); action tendencies that prepare and guide taking action (e.g. a tendency to approach); somatic and neuroendocrine responses that support and guide evaluation and action (e.g. dopamine release in reward pathways); motor expressions that make up the physical actions that occur in response to an event (e.g. smiling and approaching movements); and feelings, the aspects of these components that can be subjectively experienced (e.g. feeling joyous) [35].

Creative ideation refers to the generation of novel and effective ideas. Ideation is an integral part of the creative process, where it facilitates the generation of sufficient original material from which effective ideas can be developed [8, 28]. Creative ideation involves two major components, a generative component which enables the integration of features and concepts from already procured knowledge into ideas, and an evaluative component which appraises the generated ideas [25]. Creativity during ideation is influenced by the flexibility with which information is made available to the generative process, by the functioning of working memory, and by motivational factors that ensure an increased investment of resources to attain the goals of an idea generation process [3, 25, 28].

The link between emotion and creative ideation can be explained by the adaptive change that forms part of an emotion, and its influence on the execution of the idea generation process [10]. Typically two aspects of emotions augment creative ideation. First, there is a link between positive emotion (e.g. joy, pride) and the flexibility with which a flow of information is made available to the generative process, such that increased flexibility increases the likelihood that original ideas are generated [1, 2, 3]. In addition, there is a link between emotions such as joy or anger that associate with an approach action tendency (i.e. the tendency to pursue something positive), and increased effort investment and engagement [3, 34], such that increases in effort and engagement ensure sufficient cognitive and motivational resources are invested to enable creativity during idea generation. In this paper, we focus exclusively on the link between positive emotion and creative ideation.

Interactive systems designed to target the emotion-creativity link are relatively rare. First, there is a line of research that focuses on emotion induction (or mood induction), which typically implements techniques developed for experimental purposes on digital platforms [24, 27]. For instance, showing positive rather than negative pictures during creative problem solving and idea generation tasks enabled creativity on a crowdsourcing platform [24]. Second, there is a line of research aimed at developing interactive systems that help regulate the emotions that are caused during a creative activity [9, 11, 29]. For instance, systems that impose using arm gestures designed based on motor expressions that associate with positive rather than negative emotions, and approach rather than avoidance action tendencies, up-regulate positive emotion, and augment creativity during idea generation and insight problem solving [9]. However, no interactive systems exist that explicitly attempt to cause emotion, rather than induce emotion in a more indirect manner, to influence the emotion-creativity link. In this paper we develop such a technology.

CAUSING EMOTION

Cognitive appraisal theory describes the way in which appraisals, or perceptions, of events cause emotional responses [26, 32, 35]. These appraisals typically drive the changes in other components of an emotion, which shape its adaptive response (**Figure**). According to this theory, appraisals that imply goal-conduciveness and goal-obstruction differentiate positive from negative emotions. Goal-conduciveness and goal-obstruction refer to the way in which an event influences the progress toward attaining the individual's goals. That is, if the event implies that the current situation can lead to or led to attaining the individual's goals, positive emotion is elicited, but when it implies the reverse, negative emotion is elicited. Other appraisals (e.g. of cause, coping potential, and norm violation) further differentiate the type emotion that unfolds (e.g. the difference between the positive emotions of joy and pride). See [26, 32, 36] for overviews.

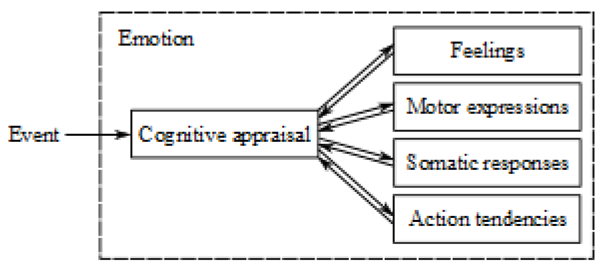

Figure 1 Appraisal-centered interpretation of emotion (after [26, 36]). Bi-directional arrows represent feedback relations among the emotion components.

There are, however, two additional factors that need to be taken into account to enable these appraisals to lead to a sufficiently strong emotional response to impact the link between emotion and creative ideation. We believe that both these two factors need to be taken into account when designing our interactive system.

First, interactions between appraisals moderate the intensity of an emerging emotion [5, 41]. So, in addition to the influence of appraised goal-conduciveness or -obstructiveness on positive or negative emotion, the appraised goal-relevance of an event, i.e. the evaluation of how strongly the event affects the individual's current goals, moderates the intensity of the resulting positive and negative emotions [22, 30]. For instance, when primed with achievement goals, performance feedback that is positive (success) and negative (failure) can elicit positive and negative emotions whose intensity varies according to the appraised goal-relevance of the feedback [22]. This suggests that an event should be perceived as both goal-relevant and goal-conducive to increase the intensity of the emotion caused.

Second, feedback connections among appraisal processes and among other emotion components (**Figure**), can create a temporary disposition to have the same emotion that was initially caused when they were first manipulated [23, 35, 38]. Thus, appraising an event in a particular way increases the likelihood that subsequent events will be appraised in a similar manner [38]. It follows that when appraisals of a certain kind happen more closely together, this enables the emergence of the associated emotional response [32]. For instance, if there are only a few goal-conducive events over a period of time, one might feel slightly positive, but when something obstructive happens, one's emotional state might be prone to change. However, if the rate of goal-conducive events increases, positive emotion will emerge in a way that is more intense, and less prone to negative influences [23, 32]. Therefore, a certain rate of goal-conducive events is likely also to be necessary to cause a sufficiently strong emotional response for our approach to be effective.

Interactive systems designed to model, recognize, and communicate emotions are becoming increasingly pervasive [36]. However, technologies designed to intentionally cause emotion are relatively rare. Recent work includes priming using digital media [17], adaptive music selection [43], and affective mirrors [37]. However, most research has focused on invoking emotion by mimicking social and affective interactions between a user and an interactive system, such as an avatar or robot [36]. The work presented in this study is more closely related to technologies, such as gaming technologies that target reward [21]. Similarly, technologies for behavior change and persuasion [15], and the more recent positive computing, which focuses on supporting well-being and human potential [6], incorporate cognitive appraisal theory implicitly or explicitly. Technologies that explicitly target appraisal processes, with the goal to cause emotion, however, are rare. In this paper we develop such a technology, by manipulating the cognitive appraisal processes that happen during creative ideation.

CAUSING EMOTION TO AUGMENT CREATIVITY

The existence of an evaluative component in the creative ideation process, as mentioned above, implies that appraisals form an integral part of this process [25, 28]. We assume that a cognitive appraisal theory of emotion [32, 35], can also be applied to the appraisals that form part of the ideation process [25, 28], and that a technology that is designed to influence the appraisals that form part of positive and negative emotion, can therefore help to intentionally cause positive and negative emotions during creative ideation.

Events that are goal-relevant within the context of creative ideation can be found by examining the function of ideation in the creative process as a whole. Typically, the function of the generative component of creative ideation is to come up with sufficient original material during the early stages of a creative process, whereas other goals, such as developing effective ideas, become more important during later stages [8, 28]. This is reflected in people's judgment of creativity, in which originality can weigh stronger than effectiveness for ideas developed in a creative ideation task [cf. 16]. This indicates that within the context of creative ideation, the appraised originality of an idea has at least some goal-relevance.

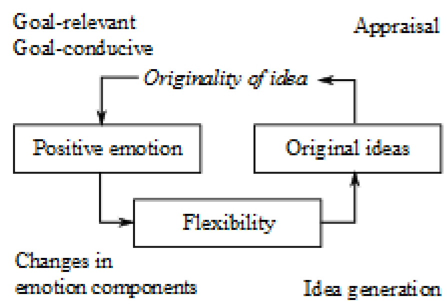

Figure 2 Impression of the hypothesized link between positive emotion, flexibility, and the generation of original ideas.

It follows from the above that generating original rather than unoriginal ideas is goal-conducive rather than goal-obstructive. Indeed, the amount of original ideas [11], and the percentage of ideas that are original [9], rather than the total amount of ideas, or the variety of the semantic concepts used in the ideas, have been shown to correlate positively with the intensity of positive emotion during idea generation. This indicates that generating more original ideas increases the prevalence and the intensity of positive emotion, whereas generating more unoriginal ideas increases the prevalence and the intensity of negative emotion. We conjecture that an increase or decrease in the rate of appraised original ideas can thus drive a positive feedback loop between appraising originality, positive emotion, and generating original ideas (**Figure**), which enables the emergence of a sufficiently strong positive emotion to lift both emotion and creativity simultaneously, and robustly.

An interactive system that targets the rate at which original and unoriginal ideas are produced can therefore be assumed to target the link between positive emotion and creative ideation. This would be the first interactive system that explicitly targets the way emotions are caused during a creative task [cf. 9, 11, 24, 27, 29]. Next we describe the implementation of such a system.

INTERACTIVE SYSTEM

To evaluate our conjectures, we developed an interactive system that is designed to influence the appraisal processes underlying positive and negative emotion during creative ideation. First, the system is capable of estimating the originality of an idea in a human-like way, in real-time. Second, the system is designed to manipulate feedback on the originality of an idea in such a way that the user's ideas appear less, the same, or more original than they really are. Finally, the system enables textual input of ideas, and presents the manipulated feedback on those ideas after typing, so that this can help the user to appraise his or her own ideas, with the aim of influencing the user's appraisals of their ideas and thereby increasing their creativity.

Estimation of originality

We operationalize originality as the statistical infrequency of an idea [31]. It follows that the frequency of an idea in a large collection of ideas about a particular subject might indicate the originality of that idea. Calculating originality thus requires a way of 1) representing ideas, 2) representing the space of ideas about a particular subject, and 3) using that idea space to estimate the originality of a new idea. See [16, 20] for related approaches.

Idea representation

In our system, an idea is represented as an unstructured collection (set) of word senses and related concepts. To generate this representation, the system takes an idea in natural language, disambiguates the part-of-speech of the words in the ideas [19], extracts the verbs and nouns, and then disambiguates the word sense of these verbs and nouns [4]. We assume that most of an idea's meaning is contained in the verbs and nouns in that idea. To make this approach less sensitive to different ways of phrasing the same idea, the IS-A (e.g. a house is a building) and PART-OF (e.g. a room is part of a house) relations of the extracted senses are retrieved from WordNet [13] to form a concept network for each idea.

Idea space generation

To be able to estimate the originality of an idea the system requires an idea space. This is created by taking a large collection of ideas, extracting the word senses from these ideas as previously described, and storing and counting the frequency of all these word senses. For this study we used the ideas that had been generated in previous studies using the same idea generation task that we will use in this study. These were kindly donated by [9, 18, 39, 40] (Table 8). This enabled us to generate three idea spaces, representing ideas about using a brick, a paperclip, and a knife.

Estimation of originality

To estimate the originality of a new idea the system extracts the concepts from this idea and retrieves the frequencies of these concepts from the idea space representation. For each idea the system summarizes the frequencies of the extracted concepts, or senses (including the associated senses) by computing the grand mean. That is, the mean of the means for each of the senses and their associated concept networks. This is done to insure that the contribution of each sense is not strongly dependent on the amount of semantically related senses found in WordNet, and to reduce the dependency of the scores on the amount of verbs and nouns that are present in an idea. The system then computes the percentile rank of the grand mean relative to the grand means of all the ideas used to generate the idea space for a particular subject. This yields a ranked originality estimate that ranges between 0 (=very unoriginal) to 100 (=very original). This is the system's estimate of originality that is used in the study.

Subject	**n-people**	**n-ideas**	**Taken from**
Brick	409	3504	[9, 18, 39, 40]
Paperclip	210	2128	[18]
Knife	242	1698	[39]

Table 120 Characteristics of the idea collections.

Pre-study: Human-likeness of the systems estimates

To investigate whether the system's estimates corresponded with human estimates we asked people to estimate the originality of 45 ideas (15 for each subject in Table 8). We asked people to use a Likert scale from 0 to 10 (0=very unoriginal, 10=very original) to 1) estimate how original they thought each idea was, and 2) state what was the lowest and the highest score that they felt could reasonably be given for each idea. Thirty-one people (16 females, 15 males, M_{age}=34.6, SD_{age}=9.87) rated the ideas in this way. These people were students and employees of a UK and a Dutch university, and did not participate in the main experiment. The same set of ideas was also rated by the developed system.

To test the consistency of the human ratings of originality and compare these with the system's ratings we first calculated the mean correlations between the participants' ratings (averaged using Fisher's z-transform). The results showed that the originality estimates by the participants correlated on average weakly to moderately to each other, $.260 < \bar{r} < .673$, with $\bar{r}=.526$. The mean correlation between the system's estimates and the estimates of the participants was similar, $\bar{r}=.453$. This indicates that people rate the originality of ideas in a manner that has limited consistence, and subsequently, so does the interactive system. This supports our assumption that a collection of ideas about one subject can be used to estimate the originality of an idea in a manner that is consistent with human estimates.

Feedback manipulation

For our experimental purposes we enable the system to manipulate the feedback it provides on ideas so that it seems to users that their ideas are 1) less original than they might expect (negative), 2) similar to what they expect (neutral), or 3) more original than they expect (positive). To make sure that these feedback manipulations are believable (e.g. not too positive that the user would not take the feedback seriously anymore), we used the data from the pre-study described above to fit three mapping functions (Table 9) that could map the originality of an idea as calculated by the system to an appropriate rating for use in the positive, neutral or negative conditions, as described below.

All the functions were generated using curve fitting (without an intercept). For the neutral manipulation we fitted the systems unmanipulated estimates, with the human estimates. The resulting function maps the system's unmanipulated estimates to approximate to the originality appraisals that people usually expect. To obtain the negative and positive mappings we fitted the human estimates with the lowest and highest scores the participants felt could reasonably be given, using a quadratic function. The resulting functions map the estimates that are processed by the neutral mapping, to originality estimates that are worse or better than people typically expect.

Feedback	Mapping function
Negative	$f(x) = .441x + .004x^2$
Neutral	$f(x) = .814x$
Positive	$f(x) = 1.794x - .008x^2$

Table 2 Generated mapping functions for the negative, neutral, and positive feedback manipulations.

We assume that if users take the manipulated feedback into account as part of the evaluative component of their idea generation process, then these manipulations should influence the way they appraise their ideas, and therefore the link between positive emotion and creative ideation, as explained above.

Feedback presentation

To enable basic textual input of ideas and effectively communicate the feedback on those ideas we developed a user interface. Users can type in their ideas in text blocks using the English language. Upon pressing ENTER the system estimates the originality of an idea, and maps this score to an output value using the pre-specified negative, neutral, or positive feedback manipulation. The resulting output is presented as informational feedback about the idea the user just generated (**Figure** 3). The feedback is presented by using a colour code (red= unoriginal, orange= somewhat unoriginal, amber= somewhat original, green= original), and numerically using the manipulated ranked estimate of originality.

We assume that presenting the feedback right after each idea is generated, collides with the moment that the user will anyway tend to evaluate his or her idea, so that the system can inform the user's appraisals of the originality of his or her own ideas, which may then target the hypothesized link between positive emotion and creative ideation.

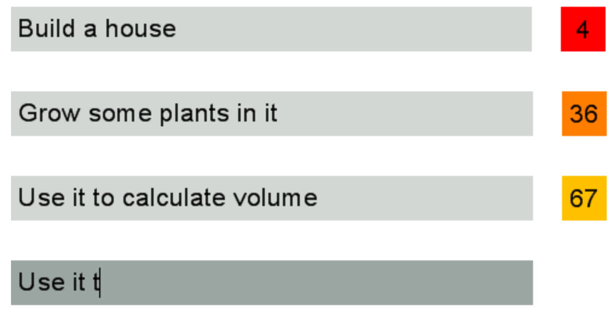

Figure 3 A screenshot of the way feedback is presented showing text entry (left), and feedback (right). The ideas and feedback shown here are responses to the brick as a subject, with the negative feedback manipulation.

Hypotheses

To put our theoretical conjectures and developed interactive system to the test, we experimentally test the following four hypotheses (Table 10).

#	Hypothesis
H1	Positive, rather than neutral or negative manipulation of computational feedback augments creativity during idea generation.
H2	Positive, rather than neutral or negative manipulation of computational feedback causes positive emotion.
H3	Negative, rather than neutral or positive manipulation of computational feedback causes negative emotion.
H4	Positive, rather than neutral or negative manipulation of computational feedback causes positive emotion, which augments creativity during idea generation.

Table 3 Hypotheses

METHOD

To test our hypotheses we used an experimental within-subject design. Each participant did three idea generation tasks using the interactive system. For these three tasks the negative, neutral, and positive feedback manipulations described above were used, for the brick, paperclip, and knife subjects. The manipulations and the subjects that were used were randomized to prevent research bias, and we used a cover story so that participants were not aware that the feedback was manipulated. In total, 49 people (25 women, 24 men, M_{age}=30, SD_{age}=8.38) participated in our study. Two participants guessed the purpose of the study and five people reported to have tried to game the interactive system by typing in bizarre ideas to gain high originality scores during one or more of the tasks. We removed these cases from further analysis to ensure that these possible extraneous sources of variation did not influence testing the hypotheses. This resulted in 134 usable cases. All participants were students or employees of City University London.

Idea generation tasks

To measure the participant's momentary creative ideation abilities we used the commonly administered alternative uses task (AUT) [33]. The AUT requires participants to generate as many as possible original, creative uses for a common object within a specified amount of time (4 minutes in our study). Participants used the interactive system to do the AUT three times, with the brick, paperclip, and knife as a subject, in random order.

Assessment of originality

We used the system's own originality estimates to calculate an originality coefficient for each participant after each task as follows. Any idea scoring above the 75th rank, according to the unmanipulated estimate calculated by the system, was counted as an original idea (26% of the ideas in this study). For each participant, we divided the number of original ideas by the total number of ideas generated during a task to obtain the participant's originality coefficient for that task. This approach is shown to have more external validity than other common objective ways of assessing originality [31].

Assessment of emotion

At the end of each task, the participants used Likert scales with emotion words on opposite ends to rate feelings of satisfaction (1=not satisfied, 9=very satisfied) and frustration (1=not frustrated, 9=very frustrated) they had experienced during the task. We assumed that these would reflect the type of negative and positive emotions typically associated with goal-conduciveness and goal-obstruction while pursuing a goal under time pressure in this way [32, 35]. Note that feelings only reflect aspects of the emotion components that can be subjectively experienced [35]. Therefore, these measures are a proxy to assess positive and negative emotion.

Manipulation checks

It is conceivable that the feedback manipulations could have made the system's estimates less believable, rather than having the intended effects. To check whether the feedback manipulations in fact led to the intended influences on appraised originality of ideas, the participants used a Likert scale to rate their own creative performance after each task (1=worse, 9=better than expected), as well as how reliable the participants thought that the feedback was (1=very unreliable, 9=very reliable).

Procedure

Upon arrival the participants were seated at the computer and introduced to the study. We used a cover story that informed the participants that we were testing *"... the efficacy of using computer supported idea evaluation,"* but withheld information about the actual experimental conditions until the end of the experiment. Informed consent was signed, and the participants filled in a brief questionnaire to collect personal data. We then explained that they would do three AUTs during which our interactive system would provide feedback about the originality of their ideas. For the AUTs we emphasized that *"...the goal* is to come up with as many original, creative, uses of a *common object as possible"*. For the system's feedback we emphasized that participants should *"... use the feedback as* a guide that helps you during your idea generation *process."* A picture of the subject used during each AUT was shown just before each task. Each task took exactly 4 minutes during which time participants could type in their ideas. After each task, participants filled in a questionnaire that was used to assess emotion and enable the manipulation checks described above, and also included filler questions about the way they used the system. After the experiment ended, the true purpose of the study was explained, and we gauged whether the participants had guessed this purpose, had tried to game the feedback by typing in bizarre ideas, or had problems using the system otherwise. To compensate the participants, we handed them a £5 voucher for a large online retailer, and a chocolate bar.

Analysis

To analyze the data from our study, we used linear mixed model (LMM) analysis with two levels [14]. The feedback manipulations were entered as the repeated measures fixed effects at level-1, with random intercepts for the participants nested at level-2. To obtain a suitable covariance structure we entered the data with different covariance structures and minimized the -2 Log likelihood (-2LL) and the model's degrees of freedom. We only accepted models with more degrees of freedom when the decrease in -2LL significantly differed from a simpler model given the χ^2 distribution [14]. For each of the dependent variables we arrived at the scaled identity covariance structure as the best fit, which is used to report our results in the following section.

RESULTS

To make sure that the feedback manipulations targeted the way participants appraised the originality of their ideas as intended, we first carried out two manipulation checks. LMM analysis showed that the effect of feedback manipulations on perceived creative task performance was significantly different in the different conditions, $F(2, 87.86)=55.19$, $p<.001$. However, the perceived reliability of the system's feedback was not significantly different, $F(2, 87.91)=.554$, $p=.577$. This indicated that the feedback manipulations had the intended effect, which helps validate this study within our theoretical framework about the link between originality and cognitive appraisal processes.

To check whether positive and negative emotion influenced creativity across the tasks, we correlated the originality, satisfaction (positive emotion), and frustration (negative emotion) data. Because the data were repeated measures, person-mean centering was used to remove between-person variance [cf. 12]. The results showed that there was a significant positive correlation between satisfaction and originality, and a significant negative correlation between frustration and originality (Table 4). These findings indicated that across all tasks there was a relationship between positive emotion, negative emotion, and creative ideation, which helps validate this study within the context of our theoretical framework about the link between positive emotion and creative ideation.

DV	1.	2.	3.
1. Originality	-		
2. Satisfaction	.382**	-	
3. Frustration	-.438**	-.733**	-

Table 4 Pearson correlation coefficients between the dependent variables originality, satisfaction, and frustration (variables were person-mean centered). *p<.05, **p<.001.

IV	Originality	Satisfaction	Frustration
Negative	.225 (.142)	3.42 (1.71)	5.87 (1.70)
Neutral	.254 (.119)	4.80 (1.70)	5.13 (1.77)
Positive	.292 (.145)	6.14 (1.50)	3.80 (1.89)

Table 5 Means and standard deviations (between parentheses) of the dependent variables for each treatment.

IV	Originality	Satisfaction	Frustration
Negative	-.067* (.026) [-.120 -.015]	-2.70** (.29) [-3.28 -2.11]	2.07** (.31) [1.46 2.67]
Neutral	-.036 (.026) [-.088 .016]	-1.32** (.29) [-1.90 -.73]	1.33** (.31) [.72 1.93]
Positive	.[a]	.	.
Intercept	.292* (.021) [.249 .334]	6.12** (.24) [5.65 6.61]	3.81** (.27) [3.29 4.34]

Table 6 Estimates of fixed effects of the feedback manipulations on satisfaction, frustration, and originality. Unstandardized estimates, standard errors (between parentheses), 95% confidence intervals (between square brackets). *p<.05, **p<.001. [a]Data relative to the positive condition, as modelled by the intercept.

The means and standard deviations of the dependent variables originality, satisfaction, and frustration for the three feedback manipulations are presented in Table 12. To test whether the feedback manipulations influenced originality, satisfaction, and frustration we performed LMM analysis on each of these variables individually (Table 13).

Estimates of fixed effects showed a significant difference between the mean originality coefficients for the feedback manipulations, F(2, 89.74)=3.33, p=.040. Compared to the positive condition (which corresponds to the intercept shown in Table 13), participants were less likely to generate original ideas in the neutral condition, and even less in the negative condition. Note however, that despite this trend, only the difference between the negative and the positive conditions was significant. The findings indicate that positive, rather than neutral or negative manipulation of computational feedback augments creativity during idea generation. This supports hypothesis H1.

Estimates of fixed effects also showed a significant difference between the mean satisfaction ratings for the feedback manipulations, F(2, 89.86)=42.27, p<.001. Compared to the positive condition, participants reported significantly less satisfaction in the neutral condition, and even less satisfaction in the negative condition. The findings indicate that positive, rather than neutral or negative manipulation of computational feedback causes positive emotion. This supports hypothesis H2.

Finally, estimates of fixed effects showed a significant difference between the mean frustration ratings for the feedback manipulations, F(2, 89.94)=23.55, p<.001. Compared to the positive condition, participants reported significantly more frustration in the neutral condition, and even more frustration in the negative condition. The findings indicate that negative, rather than neutral or positive manipulation of computational feedback causes negative emotion. This supports hypothesis H3.

	Originality	Satisfaction	Frustration
Repeated measures	.015** (.002) [.011 .020]	1.90** (.29) [1.41 2.55]	2.05** (.31) [1.53 2.75]
Intercept (subjects)	.005* (.002) [.002 .012]	.73* (.30) [.33 1.65]	1.06* (.38) [.52 2.13]

Table 6 Estimates of covariance for the LMMs. Unstandardized estimates, standard errors (between parentheses), 95% confidence intervals (between square brackets). *p<.05, **p<.001.

In terms of model quality, the estimates of covariance showed that the feedback manipulations (repeated measures, Table 14) represented the majority of variability. However, in all cases the variance for the random intercepts (participants) was significant as well (intercept, Table 14), which shows that there were variables that could explain differences between the individuals in the relationship between the feedback manipulation, and originality, satisfaction, and frustration, that we did not measure.

IV	ACME	ADE	Total effect

Feedback manipulation → Satisfaction → Originality			
Negative	-.075** [-.119 -.037]	.007 [-.053 .068]	-.068* [-.123 -.017]
Neutral	-.037** [-.058 -.017]	.004 [-.027 .037]	-.033* [-.060 -.006]
Positive	.[a]	.	.
Feedback manipulation → Frustration → Originality			
Negative	-.037* [-.070 -.008]	-.031 [-.083 .026]	-.068** [-.117 -.020]
Neutral	-.018* [-.034 -.003]	-.015 [-.042 .012]	-.034* [-.057 -.008]
Positive	.[a]	.	.

Table 7 Multilevel causal mediation analysis of the influence of the feedback manipulations on satisfaction and frustration on subsequent originality. ACME = Average Causal Mediation Effects, ADE = Average Direct Effects. 95% Confidence intervals (between square brackets). *p<.05, **p<.001. [a]Data relative to positive condition.

To add to this, and in particular to test our fourth hypothesis concerning the role of emotion in mediating the effect of our feedback manipulations on creative ideation, we carried out a multilevel causal mediation analysis [42]. The results of this showed that, when the participant's feedback was manipulated to be neutral or more negative, they were less likely to generate original ideas than when the feedback was manipulated to be more positive. Thus the effect of the feedback manipulations on originality was mediated by the increase in satisfaction that was caused by the feedback manipulation (ACME, Table 8 top half), and the decrease in frustration that was also caused by the feedback manipulation (ACME, **Error! Reference source not found.**, bottom half). The influence of feedback manipulation on originality could only be explained by the caused differences in satisfaction and frustration, as no significant direct effects of feedback manipulation on originality were found (ADE, **Error! Reference source not found.**). In terms of the differences between the ways in which the two mediation models explained the relation between emotion and creative ideation, we found that the total effect (Total effect, **Error! Reference source not found.**) for the satisfaction model was similar to the ACME, with only little variation explained by the ADE, whereas the total effect for the frustration model was explained partly by the ACME and partly by the ADE (although not significant in the latter). This provides evidence for a causal relationship between the feedback manipulations, satisfaction, and the generation of original ideas. That is, positive, rather than neutral or negative manipulation of computational feedback causes positive emotion, which augments creativity during idea generation. This supports hypotheses H4, as well H1, H2 and H3.

DISCUSSION AND FUTURE WORK

Our findings demonstrate that an interactive system can be designed to hack into the function of cognitive appraisal processes in emotion, positive emotions in particular, and that this can be used to augment creative ideation. The findings indicate that the feedback from our interactive system influenced the way in which users appraised the originality of their own ideas. The system's manipulation of the feedback influenced satisfaction (positive emotion) and frustration (negative emotion), where providing feedback that made the user's ideas look more original than they really were, rather than the same or worse, helped cause more positive emotion, and less negative emotion (H1 and H2), and helped people to generate more original ideas (H3). The influence of the feedback manipulations on positive emotion, in this case satisfaction, explained most of the impact on creative ideation (H4).

There were also some inconsistencies in the data. Although the impact of our system on positive and negative emotion was effective, not all results for originality differed significantly. Although there is a clear trend that matches our hypotheses, the standard deviations and confidence intervals show that there is also a clear overlap between the conditions. On the one hand we can argue that using the system's estimates of originality as a measure introduces unnecessary noise into the data, which makes the rejection of the null hypothesis less likely. This is to be expected due to the limited consistency with which people, and in the same way, the interactive system, estimates originality. On the other hand, this overlap is likely to be inherent in the way the interactive system is designed to manipulate the feedback. That is, the feedback the user receives depends on the user's own ideas, which can be manipulated only so much without jeopardizing its believability. It is, therefore, likely that the system could in some cases not increase the feedback enough to increase the rate of goal-conducive events to generate a sufficiently strong positive emotion.

Another limitation is that with our experimental setup it is not possible to prove that there is a reciprocal relation between the appraised originality of someone's ideas, positive emotion, and the actual generation of original ideas, which was assumed when conceiving our approach. This leaves the results open for alternative interpretations. For instance, it could be that more negative feedback is simply more inhibiting than positive feedback. Many creativity techniques emphasize that less inhibition (e.g. deferring judgment) is key to creativity [cf. 8, 28]. It is conceivable that people experience positive and negative emotion accordingly, without any impact on a reciprocal link between emotion and creativity. However, theory [23, 32], and our own findings about the causal relation between the feedback, positive emotion, and originality are in fact more in line with our own explanation.

Overall, this study offers a novel contribution to theoretical work about the emotion-creativity link, the design of creativity support tools, and more generally to the design of interactive systems that are intended to cause emotion. From a theoretical perspective, our experimental findings corroborate existing findings on the link between positive emotion and creative ideation [1, 2, 3], and extend these findings by showing a direct causal link between positive emotion and creative ideation, within subjects. Moreover, our research provides, for the first time, concrete evidence for a link between cognitive appraisal processes, positive emotion, and originality within the context under investigation.

From the perspective of technology our approach contributes to creativity support tools by providing a novel way in which such tools can influence the emotion-creativity link [cf. 9, 24, 27, 29]. Moreover, the developed interactive system is one of the first to target creative ideation, by supporting its evaluative component [cf. 16, 20]. Note that using this particular implementation of the interactive system, beyond its experimental purpose, would require it to have a more active and sophisticated way in which it can acquire and relate ideas, to meet the variety of subjects people can generate ideas about. If such a system can be designed, then this potential promises application in different types of creativity support tools, in particular those that enable an active human-machine creative collaboration.

More generally, our approach contributes to interactive systems that are designed to help cause emotion [cf. 17, 37, 43]. In particular, this approach can be valuable in such systems because it is shown to not just influence the feelings that we associate with emotions, but also other adaptive change that associates with emotion, see [7]. This potential promises application beyond creativity support, and may extend to other situations where the adaptive potential of emotion can help people, be it to assist them in performing better at other tasks, or to enable them to support their own wellbeing [6, 15, 21, 36].

Future work will focus on explicitly targeting other cognitive appraisal processes that can be used to help cause emotions to support other aspects of creativity and the creative process in addition to ideation. For instance, a system based on our principles could attempt to explicitly target uncertainty, which forms part of anxiety, and has been linked to deep and analytic processing of information, which can help select ideas that are effective [10]. Moreover, we can extend our approach to other events that are relevant to other goals that may arise during creative ideation, such as the goal to generate effective ideas, which increases the scope of where systems such as ours can be used [8]. Focusing on temporal ways of assessing emotion [e.g. 22] could help explain how the rate of appraisals over time might be used to guide the intensity of an emotion, which could be effective since intensity in particular might hold the key to further augmenting task performance [1].

Given these positive results, we consider this study as a first step toward a novel line of interactive technologies that aim to use the function of cognitive appraisals in emotion, as a way to intentionally cause emotion, with the goal to help people to get more out of their own creative capabilities.

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Appendix F

de Rooij, A., 2014. Technical Report: Arm Expression Recognition using Acoustic Myography. Available from http://www.alwinderooij.com/publications/acousticmyography2013.pdf [Accessed 30 June 2015].

Technical report: Arm Expression Recognition using Acoustic Myography

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Keywords: Affective Computing, Arm Expression Recognition, Biomechanical Data, Machine Learning, Myography

Abstract: Recent developments within the field of affective computing are focusing on the use of expressions of affect as a means to physically interact with a technology. An integral part of such systems is the ability to accurately recognize affective expressions. An essential feature of arm expression is its variation in muscle force. One can lightly pull someone towards oneself, showing affection, or perform the same gesture in a forceful way, expressing an angry dominant position. However, the de facto arm expression recognition systems typically lack the ability to distinguish among arm expressions with varying muscle force. This brief technical report addresses this problem by developing an arm expression recognition system based on acoustic myography with the goal of assessing its feasibility for use in an affective computing context. In this report, we describe the design of an acoustic myograph, and a machine learning experiment that aims to assess the ability of machine learning techniques to classify flexion and extension arm gestures at three different levels of muscle force.

1. INTRODUCTION

Affect is of interest to researchers and developers of interactive technology because it provides a window into peoples' internal states, or some level of control over the action tendencies that are associated with human emotion (Picard, 1997). Sensor systems that are able to capture biomechanical and bioelectrical data are typically used to facilitate the interface from the human physical response to a computing technology (cf. Westerink et al., 2008, Kleinsmith and Bianchi-Berthouze, 2013). Interactive technologies typically estimate human affect to inform a system about potential behaviours of the user, and formulate an appropriate response (Picard, 1997). A more recent development is the utilization of affective expressions as physical interactions with a technology to exert some influence on other components of user affect (De Rooij and Jones, 2013, Isbister, 2011). The latter provides the context for the research presented in this technical report.

Research from the psychological sciences shows that the relationship between affect and the expressions they promote is reciprocal (Scherer, 2009). For instance, arm flexion with a low muscle force is associated with a response to something pleasant, but also amplifies the appraisal of pleasantness, and associated adaptive responses such as extended memory search or cognitive flexibility (Reimann et al., 2012). Arm extension with strong muscle force is associated with an unpleasantness response, and can also amplify our tendency to respond as if something is unpleasant. Essential within this context is not only the gesture itself or its kinematic properties, but also the muscle force with which the gesture is performed. We can flex our arms quickly but lightly, and quickly but forcefully, with both having a very different affective connotation. For instance, we can gently pull someone close to us when that person is precious, or use force when we express a dominant and angry position. If we want to utilize this potential within the context of designing physical interactions that can exert an influence on human affect, then the accurate recognition of these particular arm expressions must be an integral part of such interactive systems.

Interestingly, the de facto technologies that are used for arm and overall body movement expression recognition do not specifically allow for the measurement of muscle force (see Kleinsmith and Bianchi-Berthouze, 2013 for a review). Instead, their advantage is in computing the surface geometric and kinematic properties of an arm expression. This however, is a limitation for the application of the affective computing context described above. For this reason, we look into a technological solution that can potentially be used to infer muscle force as well as the particular types of gesture characteristics of arm expressions of affect.

We choose to investigate this problem by listening instead of looking, using acoustic myography. Human muscles produce low frequency sounds when they are flexed or released (Orizio et al., 1996). These muscle sounds can reflect aspects of muscle force (Courteville et al., 1998, Orizio et al., 1990), and other aspects of arm expressions (Silva, 2005). To the knowledge of the authors of this technical report, acoustic myography has not been applied within an affective computing context. The goal of this research is to test the feasibility of using the biomechanical data captured by a custom built acoustic myograph to classify arm expressions at three levels of muscle force.

This technical report is organised as follows. In section 2 we provide a brief overview on acoustic myography and its use in computing. In section 3 we detail the design of an acoustic myograph designed for the purposes of this research. In section 4 we present the results of a machine learning experiment that aims to classify arm flexion and extension expressions at three levels of muscle force from biomechanical data produced by the acoustic myograph. Finally we discuss the results and detail future work.

2. ACOUSTIC MYOGRAPHY

The acoustic myograph is a device that is designed to extract biomechanical data by sensing the sounds produced by the muscles (Islam et al., 2012). The muscle sound owes its temporal and frequency features to the summation of vibrations produced by motor unit twitches that propagate through the muscle and the changes in the shape of the muscular fibers during contraction, much in analogy to the vibrations caused by a resonating string (Orizio et al., 1996). The produced vibrations can be measured with a mechanical or pressure sensor such as a microphone or accelerometer (Islam et al., 2012).

The reason for using acoustic myography within this research is its potential to sense a biomechanical feature that is essential to the recognition of arm expressions of affect, namely muscle force. Research from the physiological sciences shows that the root mean square (RMS) of the muscle sound has a linear relationship with the 20% to 80% range of muscle force (Courteville et al., 1998, Orizio, 1990). Furthermore, very high muscle force causes distinct resonant vibrations (due to physiological tremor) in the muscle sound (Silva et al., 2005). The frequency characteristics of the muscle sound are most pronounced in the range of 5 Hz to 50 Hz, and the overall frequency range associated with acoustic myography does not exceed 100 Hz (Orizio et al., 1996). We believe that these characteristics provide promising background information for the design of a technology that can recognize arm expressions of affect at different levels of muscle force.

Another approach to sensing muscle activity is (surface) electromyography, which senses the electrical discharge of the action potential sent though neurons in the motor unit. Both acoustic myography and electromyography can be used to similar ends. However, the acoustic myograph has some advantages. Sound travels further through flesh than electricity does. This allows for less precise placement of the myographs' sensor units, and for sensing deep muscles. This is in contrast to electromyography (Silva et al., 2005). Moreover, by virtue of the mechanical nature of the muscle sound, variations in skin conductance are not an issue. These advantages have popularized the use of acoustic myography over electromyography in applications ranging from prosthesis development (Silva et al., 2005) to musical interfaces (Donnarumma, 2011). Although surface electromyography for facial muscles has been used in an affective computing context (e.g. Westerink et al., 2008), acoustic myography has not.

3. SYSTEM DESIGN

To conduct our experiments in arm expression recognition we developed an acoustic myograph based on the work of Donnarumma (2011) and Silva et al. (2003, 2005). See Figure 1.

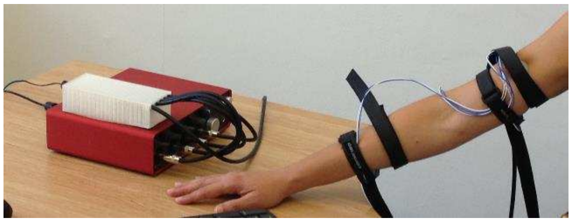

Figure 1: Overall setup of the hardware. Left: the audio interface (red box) with the circuitry for the acoustic myograph (white box). Right: the placement of the four sensor units on the arm.

The circuit design for the acoustic myograph is essentially a hack of a portable audio recorder extended to fit four omnidirectional electret condenser microphones (range 20-20000Hz) into one circuit (Figure 2). These microphones do not pick up the whole range of human muscle sounds due to their limited frequency range, sometimes only capturing part of the resonance of the sounds produced by the muscles, but were chosen for pragmatic reasons. We use an audio interface (FocusRite Scarlett 18i8) with microphone pre-amplifiers to amplify the signals and further improve the signal to noise ratio. The audio interface is then used to route the signals to a computer. Aside from pre-amplification there are some advantages of using a specialized audio interface over more general purpose micro-controller units to import signal data, such as the support of high sampling rates, and dedicated processing.

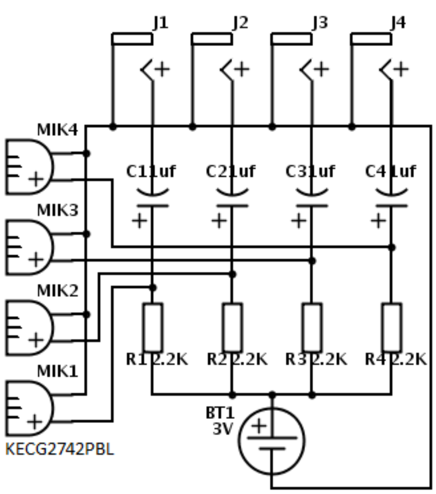

Figure 2: Circuit design of our developed acoustic myograph.

Direct placement of the microphones on the skin blocks the biomechanical resonance from being sensed. This can be solved by elevating the microphones slightly above the skin. Based on the work by Silva et al. (2003) we designed silicone cases that can be placed directly on the skin, and can hold the microphones a little over 2mm above the skin, at a fixed distance, preventing direct contact (Figure 3). Silva's experiments have led to recommendations for the design and dimensions of cases for the microphones such that the signal to noise ratio is maximized. The use of a cylindrical air chamber amplifies the resonance of the muscles, while the isolating properties of silicone help block external noise. These recommendations are used in the design of our silicone cases. Each of the sensors' units is attached to a Velcro strap such that the units can each be placed and fixed above the muscle groups on the arm that are of interest (Figure 1).

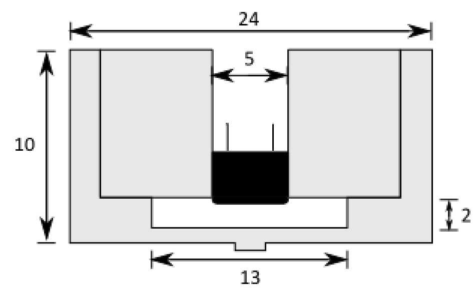

Figure 3: Design of the silicone casing for the sensor units. Legend: Greyish notes the silicone parts, black notes the electret condenser microphone. Dimensions are in mm.

The signals from our four sensor units are imported at a 44100 Hz sampling rate per channel in real time using the Pure Data real-time graphical dataflow programming environment, via the audio interface. The sensor data is down-sampled by taking the RMS of audio vectors using a Hamming window of size 256 at an offset of 128 samples. This choice is motivated by two observations from the literature on acoustic myography. First, the RMS of human muscle sounds has a linear relationship with a large range of muscle force (see Section 2). The conversion to RMS is therefore meaningful within the context of sensing muscle force. Second, the offset for sampling the windows narrows the frequency domain of the muscle signals' sampling rate to approximately 345 Hz. The muscle sounds' frequency characteristics fall well within that range (Section 2). The resulting RMS signals are available for further processing through the OSC protocol.

4. MACHINE LEARNING EXPERIMENT

A machine learning experiment was designed to assess the feasibility of using the acoustic myograph described in section 3 for the recognition of flexion and extension arm expressions at three different levels of muscle force.

4.1 Data Collection

We recruited 8 participants (M_{age}=32, SD_{age}=4.5, 5 males, 3 females, 7 right-handed, 1 left-handed) to record biomechanical data using the acoustic myograph. The participants were all students and researchers from City University London. No incentives were offered in return for participation. None of the participants were familiar with the use of myography. Data collection took a total of 20 minutes per participant.

At the start of the experiment the acoustic myograph was strapped onto each participants' dominant arm with the sensor units placed above the biceps and below the triceps, and above the flexor capri and below the extensor capri muscles (see Figure 1). Each of the sensor units were placed at the fullest part of the muscles (muscle belly), which should produce the widest range of RMS values. These muscles are actively involved in performing flexion and extension arm expressions. A computer was placed in front of the participants so that they could annotate their own expressions. We let them familiarize themselves with the acoustic myograph and the annotation system and then we got started.

Each participant was instructed to perform arm flexion and extension expressions with varying speeds, but with a consistent small, medium, and hard muscle force. Additionally, the participants were instructed to perform the expressions, hold the muscle tension for at least a second, and then release the arm expression. Each expression was repeated for a minimum of 5 times. While performing the expressions, the participants annotated their expressions by holding the 'a' key pressed down, and the release of the expression was annotated by holding the 'r' key pressed down. Switching between annotation of expressions and the levels of muscle force was done by the researcher. When no key was pressed down the incoming data was automatically annotated as '0', meaning that it captured either nothing (sensor noise) or it captured other movements that are not the expressions we aim to classify in this experiment. See Table 1 for an overview on the annotation structure.

Table 1: Overview of the annotation structure of the used arm expressions, their components, and variations in muscle force.

Component	Expression	Force	Label
Attack	Arm Flexion	Small	1
		Medium	2
		Hard	3
	Arm Extension	Small	4
		Medium	5
		Hard	6
Release	Arm Flexion	Small	7
		Medium	8
		Hard	9
	Arm Extension	Small	10
		Medium	11
		Hard	12
Nothing/ Other			0

4.2 Feature Extraction

The system is designed to extract temporal features from the collected data by sampling windows at varying sizes every 10 samples, and computing four temporal descriptors per sensor unit over these sampled windows. Determining the best performing window size is done by a brute force grid search (see Section 4.3 for the set-up). A relatively large window size was chosen, which differs from temporal pattern recognition approaches and follows the approach by Silva et al. (2005). The annotations that are part of the incoming data are only passed when a window captures 95% of one type of annotation. This essentially filters out most expressions that are smaller than the used window size.

The four temporal descriptors used are: the mean over the RMS values, which may intuitively capture much of the muscle force associated with the signal (see Section 2); the variance to indicate the spread around the mean; the skewness to indicate where the overall weight of the RMS values lie within the window, which might give some intuitive indication of how the force in different muscles is distributed over an arm expression; and the kurtosis, which might intuitively give an indication of tremors caused by forceful movements (Section 2.).

Finally, the resulting feature set is standardized. No further feature selection was done. The feature extraction procedure results in a string of feature vectors and a string of annotations, which can be used for training and testing using machine learning classification.

4.3 Classification

We applied five machine learning classification algorithms to the extracted feature vectors: Decision Tree Classifier based on the CART algorithm, K Nearest Neighbours, Logistic Regression, Naïve Bayes using a Gaussian distribution to model each individual class, and a Support Vector Machine (SVM), varying the use of a linear and non-linear kernel (radial basis function), using a one-vs-one scheme for multi-label classification (see Pedregosa et al., 2011). The parameters for each algorithm are optimized based on a comparison between the algorithms' performance in terms of prediction and recall accuracy (f1 statistic) using a brute force grid search. The parameters that yield the best results per classifier are kept. The extracted feature set was randomly split into a set for training (60%) and a set for testing (40%) the classifiers.

The performance of the classifiers on the presented biomechanical data is assessed in terms of average precision and average recall ability. Precision is defined as the ratio that describes the ability of the classifier not to label a sample that is negative as positive. Recall is the ratio that describes the ability of the classifier to assign the correct label to all positive examples (Pedregosa et al., 2011).

Table 2: Classification results for precision and recall ability for five machine learning classification algorithms.

Classifier	Precision average	Recall average
Decision tree	0.92	0.92
K nearest neighbour	0.89	0.88
Logistic regression	0.74	0.83
Naïve Bayes	0.55	0.53
SVM	0.96	0.96

The results show that the non-linear SVM (kernel: radial basis function, C=20, gamma=0.7) offers the best performance both in terms of precision and in terms of recall (Table 2). It is interesting to note that aside from lowered performance scores, the K nearest neighbours, logistic regression and Naïve Bayes (but also SVM with a linear kernel) methods were not able to correctly label any of the data in the test set associated with some of the labels. This effectively rules out their use in practice for the classification of flexion and extension arm expressions at three different levels of muscle force.

Table 3: Classification results averaged per expression characteristic from the testing set for the trained SVM classifier.

Expression characteristic	Precision	Recall
Expressions of interest	0.91	0.82
Nothing/ Other	0.96	0.99
Attack	0.91	0.85
Release	0.91	0.78
Flexion	0.93	0.81
Extension	0.90	0.82
Small force	0.91	0.79
Medium force	0.92	0.82
Hard force	0.92	0.84

To see whether there are differences among the characteristics of arm expressions that are of interest to this research we have computed the average precision and recall per characteristic (see Table 3). The classification results from the support vector machine show that the classification of data as a non-expression is more accurate than the classification of the actual expressions. This difference becomes clear when comparing the average recall for 'Nothing/Other' and the average of recall scores for the expressions of interest. The results for classifying the attack and release component of the arm expressions are relatively uniform, with a slightly lower score for release compared with attack at recall. This is to be expected because the release of an arm expression is less defined than its attack. For instance, a release can mark the transition to any other movement or no movement at all. In terms of classifying arm flexion and extension we see a uniform performance for both precision and recall. The classification of attack and release components was also relatively uniform for the different muscle forces applied, with slightly higher performance for stronger muscle force.

Overall, the support vector machine was able to classify arm flexion and extension attack and release at three levels of muscle force with reasonable performance.

4.4 Post-Processing

Further post-processing can be used to improve the performance of arm expression recognition. To this end we detail one experiment that uses a heuristic sequence correction.

Table 4: Classification results averaged per expression characteristic for the whole data set for the trained SVM classifier and sequence correction. Changes in a sequence smaller than 38 labels were ignored.

Expression characteristic	Precision	Recall
Expressions of interest	0.90	0.92
Nothing/ Other	0.99	0.98
Attack	0.91	0.94
Release	0.89	0.90
Flexion	0.90	0.92
Extension	0.90	0.91
Small force	0.88	0.91
Medium force	0.92	0.91
Hard force	0.90	0.94

The system is set up to output a string of labels as described in Table 1. Brief changes in a string of labels can be ignored, as they typically indicate a misclassification. This knowledge can be used to increase the performance of the arm expression recognition system in terms of classification recall and precision, as shown in Table 4.

5. DISCUSSION AND FUTURE WORK

The results described in section 4 indicate that support vector machines with a radial basis function kernel can be used to classify flexion and extension arm expressions of affect and distinguish between their attack and release, all at three different levels of muscle force. This satisfies the aims set for this research.

The results also indicate some caveats in the presented research. For data collection we instructed our participants to annotate their own data in real time. It is inherent to this approach that mis-annotations will occur. This negatively impacts the performance of the classification in terms of precision and recall ability. However, when applied within an affective computing context to mediate the use of physical interactions with a technology, the actual working of the system is perhaps less likely to suffer than the more precise measurements used to assess the performance of the machine learning experiments the research presented here. Future work will show whether this is problematic.

The obtained results will help develop novel affective technologies that utilize physical interactions designed on the basis of arm expressions of affect, with the goal to influence affective responses, and associated adaptive responses within the context of interactive technology. This will be the basis of future work.

Taking a broader perspective we conclude that the added value of distinguishing among expressions with varying muscle force makes acoustic myography a potentially valuable addition to the spectrum of affective arm expression recognition systems. Therefore, acoustic myography offers the potential to develop a new range of affective computing systems that utilize arm expressions as a means to target or recognize affect.

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