Creativity and Emotion: Enhancing Creative Thinking by the Manipulation of Computational Feedback to Determine Emotional Intensity

Alwin de Rooij
Tilburg center for Cognition and Communication
Tilburg University
Warandelaan 2, Tilburg, NL
alwinderooij@uvt.nl

Philip J. Corr
Department of Psychology
City, University of London
Northampton Square, London
EC1V 0HB, UK
philip.corr.1@city.ac.uk

Sara Jones
CASS Business School
City, University of London
Northampton Square, London
EC1V 0HB, UK
s.v.jones@city.ac.uk

ABSTRACT
Positive emotions can enhance the ability of people to generate original ideas, and its intensity can determine the degree to which people are able to think originally. How to design a technology that can be used to hack into this link between the intensity of positive emotion and creative thinking is, however, still an open problem. To address this we have conceived, developed, and experimentally evaluated a proof-of-concept interactive system that generates believable computational feedback about the originality of a user's own ideas in real-time. This system can manipulate this feedback to make a user's own ideas appear more or less original than people would typically judge them to be, and can also vary the order of this manipulation over time. This has enabled us to test experimentally that: (i) the order in which the positivity and negativity of the feedback is varied can be used to condition people's expectations, which (ii) can be used to later determine an intended intensity a positive emotion that a user experience, and which (iii) subsequently influence the degree to which the user is able to generate original ideas. The findings demonstrate that an interactive system can be designed to determine the type and intensity of an emotional response, in a manner that enhances the people's ability to generate original ideas.

Author Keywords
Creativity; Emotion; Expectations; Interactive systems.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

C&C '17, June 27-30, 2017, Singapore, Singapore
 ISBN 978-1-4503-4403-6/17/06…$15.00
DOI: http://dx.doi.org/10.1145/3059454.3059469

INTRODUCTION
Creative thinking can be enhanced by certain emotions [2, 15]. For instance, when people experience positive emotions, cognitive flexibility increases, which augments a human's ability to generate diverse and original ideas [1]. The intensity of positive emotion is also assumed to determine the extent to which flexibility increases, and therefore to influence the degree to which people are able to generate diverse and original ideas [cf. 2]. It follows from this that an interactive technology that causes emotions with an intended intensity could be used to augment human creativity. However, the question of how to design an interactive system that effectively makes use of this potential remains open [13, 14].

In this paper, we describe the conception, development, and experimental evaluation of one such system. Based on previous research, we conjecture that positive and negative emotions during idea generation are caused via the appraisal of the originality or unoriginality of a person's own ideas [13]. These cognitive appraisal processes not only cause emotion, and determine their type, but also condition the expectations that people will have about their ability to generate original ideas in similar, future situations 10]. Expectations, in turn, provide a frame of reference against which such appraisals determine the intensity of the positive and negative emotions caused [10]. The intensity of these positive and negative emotions then impacts the momentary capacity for human creative thought [2].

Based on this argument, we developed a proof-of-concept interactive system that generates believable feedback about the originality of a user's ideas. This is done by automatically generating feedback after a user generates an idea, and manipulating this feedback to make the user's ideas appear more, or less, original than people typically think they are. The order in which the manipulations are applied, for instance, by first making it easier and later more difficult to get positive feedback, is assumed to condition a user's expectations about its ability to generate original ideas. This can then be used to cause positive and negative emotions with an intended intensity [cf. 10],

enabling the system to purposefully augment or diminish the actual ability of the user to generate original ideas [2].

We hypothesise and demonstrate experimentally that the developed interactive system can be used to condition a user's expectations about his or her own ability to generate original ideas, and subsequently cause positive and negative emotions with an intended intensity. The intensity of positive emotions caused is shown to influence the degree to which the user is able to generate original ideas. Thus, the contribution of the present study is a demonstration that an interactive system can be designed to manipulate cognitive appraisal processes to determine the type and intensity of an emotional response, in a manner that helps people to perform better on creative idea generation tasks.

EMOTION, INTENSITY, AND 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 [30]. Emotions consist of changes in a number of emotion components, and include: the cognitive appraisal of events (e.g. I am performing well); action tendencies (e.g. a tendency to approach); somatic and neuroendocrine responses (e.g. dopamine release in reward pathways); motor expressions (e.g. smiling and approaching movements); and feelings, the aspects of the mentioned emotion components that can be subjectively experienced (e.g. feeling joyous) [30].

Creativity has been defined as the development of ideas, insights, or solutions that are both original and effective [29]. To arrive at a creative outcome, people cycle back and forth through a range of information processing steps, with the creative process consisting of: 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 [24]. The degree of creativity that people display depends on the way the steps in the creative process are executed.

Emotions can augment or diminish creativity when the effects of those emotions on the way people think and act influence the way the creative process, including idea generation, is executed favours the emergence of original (yet effective) ideas [15]. In the present study we focus on the production of original ideas during idea generation.

The emotion-creativity link

Emotions can be generally distinguished by the positive (e.g. joy, pride, satisfaction) or negative (e.g. sadness, anger, fear) experiences associated with them [30], and by their intensity, i.e. the degree to which an event drives changes in, and recruits, the emotion components [7].

Positive emotions in particular are associated with augmented creativity during idea generation [2]. Positive emotions influence the flexibility with which information is made available to conceptual combination, and idea generation processes. Hence positive emotions can augment creativity, because an increase in flexibility increases the chance that more remote concepts are combined, which in turn increases the chance that the ideas generated are original. *Negative emotions* typically are associated with diminished creativity during idea generation [2], though some exceptions to this exist as well [3, 27]. Negative emotions focus the way people think and act on the event that causes the negative emotion. This, in turn, reduces the flexibility with which information is made available to the creative process, and hence reduces the chance that original ideas are generated. Thus, negative emotions can diminish creativity when compared to positive emotions, because a decrease in flexibility reduces the chance that remote concepts are combined, and consequently reduces the chance that any ideas generated are original.

We assume that the *emotional intensity* of positive and negative emotions has a direct effect on the degree to which these emotions influence creativity. This is based on the assumption that emotional intensity reflects the degree of changes in, and recruitment of, the emotion components [7]. It follows that in the case of positive emotions, emotional intensity influences the degree of flexibility with which people are able to generate ideas [1]. Thus, the intensity of positive emotion could regulate the degree to which people are able to think up original ideas. In the case of negative emotions, and increase in emotional intensity influences the degree to which the emotion components change to facilitate an adaptive response that focuses on resolving a problem that is encountered [30]. We assume that the intensity of negative emotions subtracts from the flexibility necessary to generate original ideas, which should diminish the ability of people to generate original ideas when compared to positive emotions [cf. 2]. However, the link between the intensity of negative emotion and creativity during idea generation, however, has not been studied explicitly until now. Therefore, the possible relationship between the intensity of different emotions and creativity is still very much an unanswered question.

It follows from the above that an interactive system that can help cause positive and negative emotions with an intended intensity can be used to influence the degree to which people are able to generate original ideas.

Causing emotion

Cognitive appraisal theory describes the way in which different appraisals, or perceptions, of events in an individual's environment determine the type of emotional response that is caused [30]. Appraisals typically drive changes in the other emotion components, which shape the emotion's influence on the way people think and act. From a cognitive appraisal perspective, appraisals that indicate the *goal-conduciveness* and *goal-obstructiveness* of an event are what differentiate positive from negative emotions. Goal-conduciveness and goal-obstruction refer to the way in which an event influences the progress toward or

away from attaining an individual's goals. That is, if an event indicates that an increase in the progress to the goals of an individual, positive emotion is typically caused; but when an event indicates a move away from an individual's goals, negative emotion is typically caused. Other appraisals, e.g. whether an event is caused by someone else or yourself, or whether you are able to cope with a situation, further differentiate the type emotion that unfolds, e.g. the difference between the positive emotions of joy and pride. See [30] for an overview.

Creativity during idea generation involves cycling back and forth through information processing steps that involve conceptual combination, the actual generation of ideas based on different concepts, and the evaluation of these generated ideas [24]. 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 to provide information about the originality or usefulness of the generated ideas, which in turn shapes the way people generate further ideas [23]. Note that in this study we refer to this particular cycle simply as *idea generation*, because we believe that we cannot isolate the conceptual combinations that feed forward, and the idea evaluations that feed back from the idea generation step itself. We assume that a cognitive appraisal theory of emotion [30] can also be applied to the appraisals that form part of the evaluation of ideas, and therefore might impact conceptual combination and idea generation [23], via the way emotions influence the execution of these particular steps in the creative process [cf. 15, 24].

Events that are goal-conducive or goal-obstructive within the context of idea generation can be found by examining the function of idea generation in the creative process as a whole. First, the function 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 [11, 24]. This indicates that the generation of original ideas is the main goal that people strive for during creative idea generation. Second, previous studies have found that manipulation of the degree to which people believe that their own ideas are original or unoriginal, regardless of the ideas' actual originality, influences the degree to which they experience positive and negative emotions during idea generation [13, 14, 16]. Thus, we can assume that the generation of original ideas is goal-conducive, whereas the generation of unoriginal ideas is perceived as goal-obstructive during creative idea generation.

An interactive system that can influence the appraisal of the originality or unoriginality of a user's ideas, can therefore be used to intentionally help cause positive and negative emotions during creative idea generation.

Determining emotional intensity

Cognitive appraisal processes not only play a role in causing and differentiating emotion, they also help determine *emotional intensity* [30]. That is, they help determine the degree to which an event drives changes in, and recruits, the emotion components [7].

The intensity of an emotion is, in part, determined by the appraisal of an event against some frame of reference [19]. 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 [21, 33]. 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 [10]. 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 [21]. 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 [6]. Other appraisal processes, particular to more specific emotions (e.g. the blameworthiness of a person during anger), can also influence emotional intensity. See [6, 33] for overviews.

The cognitive appraisal processes that cause positive and negative emotions reciprocally condition the expectations that help determine the intensity of these emotions [10]. This is because expectations are formed, in part, based on how often and how recently particular events have happened, and based on how these events are appraised, in particular situations [34]. 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 [10]. Likewise, if an event repeatedly implies more progress away from the individual's goals, expectations will be lowered. The degree to which expectations are lowered or raised depends in part on the degree an event implies deviations from one's initial expectations [10]. Note that other factors (e.g. the amount of available resources, or optimism) can also influence expectations.

On the basis of the arguments set out above, we hypothesised that an interactive system that influences a user's appraisal of the originality or unoriginality of his or her own ideas could be used to condition the expectations an individual has about its ability to generate original ideas, and thereby cause positive and negative emotions with an intended intensity, thus influencing the discussed link between emotional intensity and creative thinking.

INTERACTIVE SYSTEM

Interactive systems that attempt to hack into the link between emotion, emotional intensity and creativity are

scarce. First, interactive systems have been developed that attempt to make use of the function of motor expressions in emotion regulation to modulate the intensity of emotions that are caused during a creative process [14, 16]. For instance, [14] showed that using arm gestures to trigger an audio recording device used to record creative ideas, could hack into the link between positive emotion and creativity, when these arm gestures were designed on the basis of emotion expressions that associate with positive and negative emotions. The results of this study suggested that the intensity of a positive emotion could be increased when generating an idea itself caused positive emotion and was paired with a positive recording gesture, which subsequently enhanced people's ability to generate original ideas.

Second, interactive systems have also been developed to make use of the causal function of cognitive appraisal processes in emotion (such as discussed in our theory section) [13]. For instance, a recent study used an interactive system that generates believable feedback about the originality or unoriginality of a user's ideas to increase the likelihood that users appraise their own ideas as more original or unoriginal, to intentionally increase the likelihood that users experience positive or negative emotion during idea generation. This was done by making the users' ideas appear less original (i.e. negative feedback manipulation), or more original (i.e. positive feedback manipulation). The results showed that increasing the likelihood of experiencing positive emotion indeed enhanced the ability of users to generate actual original ideas.

Although the system developed in [13] can be used to effectively influence a user's appraisal of the originality or unoriginality of his or her own ideas, we do not know whether such a system can also be used to condition the expectations an individual has about his or her ability to generate original ideas, and thereby cause positive and negative emotions with an intended intensity, and subsequently determine the degree to which people are able to generate original ideas. To this end, we redesigned the interactive system developed in [13]. We refer to [13] for more technical details of the used interactive system. In what follows below we will emphasise those aspects of the interactive system that have been redesigned.

Generating computational feedback

The interactive system operationalises originality as the statistical infrequency of a (newly) generated idea, given a large set of (previously) generated ideas about the same topic [cf. 32]. For the system to estimate originality we have collected a large set of ideas about two subjects: 3504 creative uses of a brick generated by 409 people, and 2128 creative uses of a paperclip generated by 210 people. To calculate the statistical infrequency of a newly generated idea, the interactive system compares the verbs and nouns it finds in the new idea, to the frequency of all the verbs and nouns in the large set of previously generated ideas. This was done using existing natural language processing technology, including the hun-pos tagger [20], adapted Lesk [4], and the WordNet ontology [18]. The more the verbs and nouns extracted from a new idea are found in the set of previously generated ideas, the lower the originality of the new idea. A ranked score ranging from 0 to 100 (0=very unoriginal, 100=very original) is computed based on these frequencies, to give a basic originality score.

A previous study [13] suggested that users find the computational feedback generated in this way to be believable, and relevant to their own idea generation process. This suggests that the system's feedback can be used to influence the cognitive appraisal processes that form part of positive and negative emotions during creative idea generation.

Manipulating feedback

The interactive system is endowed with the capability to manipulate the feedback it generates such that the user's ideas appear less original (*negative feedback manipulation*) or more original (*positive feedback manipulation*) than people typically believe they are. These feedback manipulations are computed by applying a function that was obtained from a previous empirical study, about the degree to which people think an originality rating can reasonably be higher or lower than the actual originality of an idea [13], to the basic originality score that the system generates. Using empirically obtained mapping functions in this way increases the likelihood that the negative feedback manipulations are not too negative, and the positive feedback manipulations are not too positive to still be believable to the user.

We assume that repeated provision of computational feedback that is manipulated in this way, can be used to condition a user's expectations about their own ability to generate original ideas, and cause positive and negative emotions, as described above.

Conditioning expectations

In addition to providing manipulated feedback in the manner described above, we also assume that the order in which the feedback manipulations are used can further enable the system to make use of the conditioning of expectations, to cause emotions with and intended type, and determine the intensity of these emotions. Based on the research we discussed, we assume that this can be done by varying the order of the feedback manipulations over two consecutive related tasks, as follows:

1) Positive feedback followed by negative feedback manipulation may condition high expectations first, and then lead people to believe they are doing much worse than they have come to expect, leading to more intense negative emotions.
2) Negative feedback followed by further negative feedback manipulation may condition low expectations

first, but as people become accustomed to these expectations, they may come to believe they are doing as expected, leading to less intense negative emotions.

3) 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.
4) Negative followed by positive feedback manipulation may condition low expectations first, and then lead people to believe they are doing much better than they have come to expect, leading to more intense positive emotions.

We assume that if users receive the computer generated feedback in a manner that is manipulated according to these order patterns, the system will effectively be able to condition expectations in the first set of manipulations, and hence cause positive and negative emotions with an intended intensity in the second set of tasks, as described in the above section.

User interface

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. Upon pressing ENTER the system estimates a basic originality score of the idea just typed, and maps this score to an output value using the pre-specified negative, neutral, or positive feedback manipulation described above. The resulting output is presented as informational feedback about the idea the user just generated (Figure 1). The feedback is presented by using a colour code, based on the manipulated scores (red = 0<25, orange = 25<50, amber = 50<75, green = 75<100), and numerically, using the manipulated ranked estimate of originality.

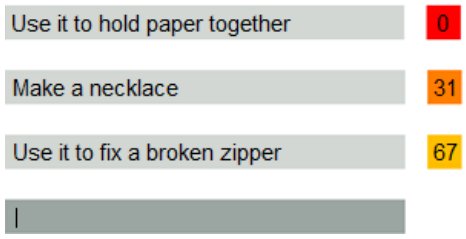

Figure 1 A screenshot of the way feedback is presented showing text entry (left), and feedback (right). The ideas and feedback shown here are responses to the paperclip as a subject, with the negative feedback manipulation.

We assume that presenting the feedback right after each idea is generated and typed in enables the system to make use of the conjectured links between expectations, emotional intensity, and creativity during idea generation.

Hypotheses

To put our conceptions and system to the test, we experimentally tested the following hypotheses (Table 1).

#	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 1 Hypotheses

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 participants' ideas. Each participant was exposed to one of the following order patterns with which the system's feedback manipulations were administered:

1. Positive feedback manipulation in task 1, followed by negative feedback manipulation in task 2 (PN).
2. Negative feedback manipulation in task 1 and 2 (NN).
3. Positive feedback manipulation in task 1 and 2 (PP).
4. Negative feedback manipulation in task 1, followed by positive feedback manipulation in task 2 (NP).

Note that (i) getting only positive feedback or only negative feedback during both tasks can be seen as a control group, i.e. the group that should not deviate from expectations; and (ii) 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. Both the feedback manipulations and the subjects used during the tasks were randomised to prevent research bias.

Participants

In total, 59 people (49 females, 10 males, M_{age}=29, SD_{age}=6.97) participated in our study. The sampling method was one of convenience. Two participants guessed the purpose of the study, one admitted not to have paid attention to the feedback, and three were identified that gamed 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 53 usable cases. Participants were students or employees from City, University of London in the United Kingdom.

Materials and measurements

Idea generation task

To gather data from which we could assess the participants' creativity during idea generation, they performed two consecutive alternative uses tasks (AUTs). The AUT is

commonly used to emulate the idea generation step in the creative process [32]. In our study participants were instructed to "*...come up with as many, diverse, and original uses for the common object as you can*", within 4 minutes. These 4 minutes were timed by the computer program, which disabled the ability to enter new ideas after the set time had passed. Time was not shown on the screen. A different common object (brick or paperclip) was used for each task. The order of presentation was randomised.

Assessment of originality

To assess *originality* we used the system's own basic originality scores. The amount of ideas generated in the second AUT that were above the 75th percentile rank was counted for each individual (24% of the total amount of ideas in this study). We only assessed ideas generated after 60 seconds, in order to avoid ideas generated when the interactive system could not yet have had a strong enough effect on emotion and its intensity. We then averaged the amount of original ideas across each individual to correct for possible differences in the number of ideas participants generated [26].

Assessment of emotion

To assess positive emotion we asked the participants to rate the degree of *satisfaction* they experienced during the second task using a nine point Likert scale (1=not satisfied, 9=very satisfied). To assess negative emotion we asked the participants to rate the degree of *frustration* they experienced during the second task, also using a nine point Likert scale (1=not frustrated, 9=very frustrated). We assumed that these emotions would best reflect the type of emotions typically associated with goal-conduciveness and goal-obstruction while pursuing a goal in a performance context [30], and that this would make it easier for the participants to recall their feelings after the tasks.

Assessment of expectations

To assess whether the feedback manipulations influenced the participants' *expectations* about their own ability to generate original ideas, we asked them to rate whether they felt that they did much worse, or much better, than they expected they would do (1=much worse than expected, 9=much better than expected).. We explicitly did not check for the expectations they had prior to each task because we were unsure whether people would be able to self-report adequately and correctly. Instead, we assumed that the degree to which the participant's own performance violated their expectations would be easier to report.

Procedure

Upon arrival at the testing session, participants were seated at a computer and introduced to the study. They were informed that we were testing *"... the efficacy of using computer supported idea evaluation."* We did, however, withhold 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 two AUTs during which our interactive system would provide feedback about the originality of each idea they generated and provided instructions about the AUT. We further emphasised 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. Right after each task ended, participants filled in a questionnaire, which contained the measurement instruments used to assess emotion and expectations. After the experiment ended, the true purpose of the study was explained, and we asked participants whether they had guessed this purpose, had tried to game the feedback during some tasks, or had any 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.

RESULTS

To check whether there exists a general relationship across the experimental conditions among expectations, satisfaction, frustration, and originality that our interactive system could influence, we used a Pearson correlation (Table 2). The results showed that there were significant positive correlations between expectation and satisfaction, expectation and originality, and satisfaction and originality; and significant negative correlations between expectation and frustration, and frustration and originality. The findings indicate that there is both a relationship between expectations and the intensity of emotion, and between emotional intensity and creativity across the experimental conditions. Thus, these findings suggest there is a precedent to further test hypotheses H1 and H2.

	1.	**2.**	**3.**	**4.**
1. Expectation	-			
2. Satisfaction	.865**	-		
3. Frustration	-.392**	-.514**	-	
4. Originality	.514**	.459**	-.363**	-

Table 2 Pearson correlation coefficients for expectation, satisfaction, frustration, and originality. **p<.001.

DV / IV	**Expectation**	**Satisfaction**	**Frustration**	**Originality**
PN	4.38 (1.71)	4.00 (2.08)	6.00 (1.63)	.170 (.145)
NN	4.79 (2.52)	4.71 (2.53)	4.71 (1.98)	.237 (.163)
PP	4.38 (1.98)	5.31 (2.10)	4.31 (2.69)	.305 (.228)
NP	7.38 (1.39)	7.00 (1.63)	3.77 (1.79)	.387 (.204)

Table 3 Mean and standard deviation (parentheses) of each feedback manipulation for expectation, satisfaction, frustration, and originality.

To test the effects of the system's feedback manipulations (independent variable, IV) on expectation, satisfaction, frustration, and originality (dependent variables, DV) we used a one-way ANOVA. The descriptive statistics are presented in Table 3.

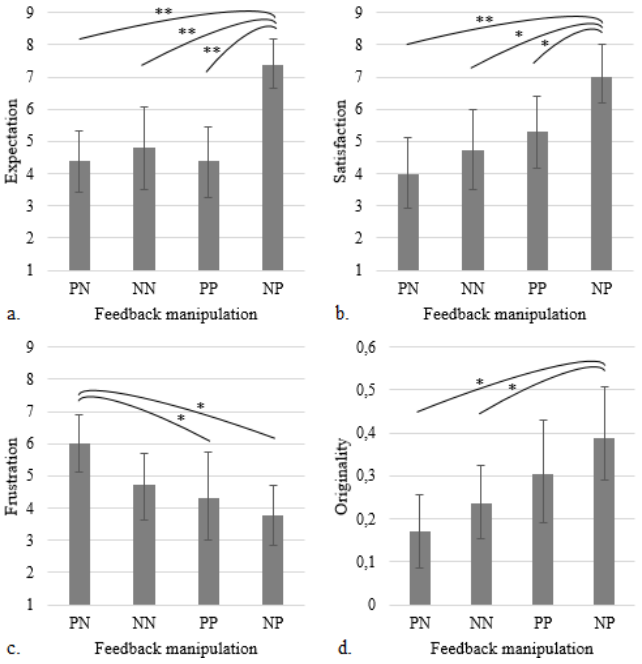

Figure 2 Graphic of the means, 95% confidence intervals (error bars), and pairwise comparisons for a. expectation, b. satisfaction, c. frustration, and d. originality for each of the feedback manipulations. *p<.05, **p<.001.

The results showed a significant effect of the feedback manipulations on *expectation*, F(3, 52)=7.11, p<.001, η^2=.30. Pairwise comparisons (uncorrected) showed that negative followed by positive feedback manipulation significantly increased the participant's belief that they did better than expected (Figure 2a). No clear differences were observed between positive followed by negative feedback manipulation, and manipulating the feedback negatively or positively in both tasks, with regard to expectation (Table 3). This indicated that there are limitations in the degree to which the interactive system is able to condition the expectations people have about their own ability to generate original ideas. This partly supports hypothesis H1.

The results showed a significant effect of the feedback manipulations on *satisfaction*, F(3, 52)=4.77, p=.005, η^2=.23. Pairwise comparisons showed that negative followed by positive feedback manipulation significantly increased the intensity of satisfaction (Figure 2b). The differences in satisfaction that resulted from the feedback manipulations (Table 3), indicate that the system can be used to cause positive emotion and determine its intensity. The results showed no overall significant effect of the feedback manipulations on *frustration*, F(3, 52)=2.77, p=.052, η^2=.14. Pairwise comparisons, however, showed that positive followed by negative feedback manipulation significantly increased the intensity of frustration (Figure 2c). The differences in frustration that resulted from the feedback manipulations (Table 3), indicate that the system can be used to cause negative emotion and determine its intensity. This partly supports hypothesis H1.

The results showed a significant effect of the feedback manipulations on *originality*, F(3, 52)=3.19, p=.032, η^2=.16. Pairwise comparisons showed that negative followed by positive feedback manipulation increased significantly the originality of the participant's ideas, when compared to positive followed by negative feedback manipulation (Figure 2d). The differences in originality that resulted from the feedback manipulations (Table 3), indicate that the interactive system can be used to influence the degree to which people are able to generate original ideas. This supports hypothesis H2.

IV	Indirect effect	Direct effect	Total effect
PN	**-3.04****	.04	**-3.00****
NN	**-2.57****	.28	**-2.29***
PP	**-2.67****	**.98**†	**-1.69***

Table 4 Estimates from the mediation analysis for the effects of the feedback manipulations (IV) on the intensity of satisfaction, as mediated by expectation. The estimates are relative to NP. $^{\dagger}p$<.10, *p<.05, **p<.001.

IV	Indirect effect	Direct effect	Total effect
NN	-.05	**-1.23**†	**-1.29**†
PP	.00	**-1.69***	**-1.69***
NP	**-1.18**†	-1.05	**-2.23***

Table 5 Estimates from the mediation analysis for the effects of the feedback manipulations (IV) on the intensity of frustration, as mediated by expectation. The estimates are relative to PN. $^{\dagger}p$<.10, *p<.05.

To test whether the effects of the interactive system on the intensity of satisfaction and frustration could be explained by its effects on expectation, we performed a mediation analysis using structural equation modeling [28].

The mediation models were set up with the feedback manipulations as IV, expectation as the mediator, and satisfaction or frustration as the DV. The results for the satisfaction model showed that the effects of the feedback manipulations on the intensity of satisfaction (Table 4, Total effect) were best explained by the effects of the feedback manipulations on expectation (Table 4, Indirect effect), rather than by something else (Table 4, Direct effect). These results indicate that the interactive system can be used to influence the intensity of positive emotion, by conditioning people's expectations.

The results for the frustration model showed that the effects of the feedback manipulations on the intensity of frustration (Table 5, Total effect) could not be explained by the effects of the manipulations on expectation (Table 5, Indirect effect), but was more likely to be better explained by something else, which we did not measure (Table 5, Direct effect). These results indicate that the ability of the interactive system to influence the intensity of negative emotion does not happen by conditioning people's expectations.

Thus, the results confirm hypothesis H1. However, the effects of the interactive system on the link between expectations and emotional intensity extends only to positive emotion.

IV	Indirect effect	Direct effect	Total effect
PN	**-.12**†	-.10	**-.22****
NN	**-.08**†	-.07	**-.15***
PP	**-.20***	.11	-.08

Table 6 Estimates from the mediation analysis for the effects of the feedback manipulations (IV) on originality mediated by the effects of the feedback on expectation and subsequent intensity of satisfaction. The estimates are relative to NP. $^{\dagger}p<.10$, *$p<.05$, **$p<.001$.

IV	Indirect effect	Direct effect	Total effect
NN	.04	.03	.07
PP	**.08**†	.05	**.14**†
NP	-.01	**.23***	**.22****

Table 7 Estimates from the mediation analysis for the effects of the feedback manipulations (IV) on originality mediated by the effects of the feedback on expectation and subsequent intensity of frustration. The estimates are relative to PN. $^{\dagger}p<.10$, *$p<.05$, **$p<.001$.

To further explore whether the effects of the system on the expectation-satisfaction-originality link, we set up a mediation model with the feedback manipulations as the IV, expectation and satisfaction in series as the first and second mediator, and originality as the DV. The results showed that the effects of the feedback manipulations on originality (Table 6, Total effect) were best explained by the effects of the feedback on the link between expectation and the intensity of satisfaction (Table 6, Indirect effect), rather than by something else (Table 6, Direct effect). These results indicate that the interactive system can be used to influence the intensity of positive emotion, by conditioning people's expectations; and that the system's influence on the intensity of positive emotion affects the degree to which people are able to generate original ideas.

To further explore whether there is a link between the intensity of frustration and originality, we set up a mediation model with the feedback manipulations as the IV, frustration as the mediator, and originality as the dependent variable. We did not include expectation because we have found no evidence to suggest it's inclusion in our data (see Figure 2c and Table 5, Indirect effect). The results showed that the effects of the feedback manipulations on originality (Table 7, Total effect) could not be explained by the effects of the feedback on the intensity of frustration (Table 7, Indirect effect), and only in one case (when comparing positive followed by negative, with negative followed by positive feedback manipulation), by something else, which we did not model (Table 7, Direct effect). These results confirms that the system influences originality, but not via its link with the intensity of frustration.

Thus, the results confirm hypothesis H2. However, the effects of the interactive system on the link between emotional intensity and creativity during idea generation extends only to positive emotion.

DISCUSSION

Our study demonstrates that an interactive system can be designed to manipulate cognitive appraisal processes to determine the type and intensity of an emotional response, in a manner that helps people to perform better on idea generation tasks that require creativity.

The results suggest that the order in which the interactive system provides manipulated feedback about the originality of a user's ideas to make them appear more, or less original, can be used to condition people's expectations about their own ability to generate original ideas (Figure 2a), cause positive emotion - satisfaction - (Figure 2b) and negative emotion - frustration - (Figure 2c), and influence the actual ability of people to generate original ideas (Figure 2d). The influence of the interactive system on expectations enables the system to cause positive emotion and determine its intensity (Table 4). The influence of the interactive system on the intensity of positive emotion also helps to enhance people's actual ability to generate original ideas (Table 6). Thus, these findings indicate that the interactive system is able to cause emotion of an intended type, and determine the intensity of that emotion by conditioning people's expectations about their ability to generate original ideas (H1). Furthermore, the system's influence on the intensity of positive emotion also influences the degree to which people are able to generate original ideas (H2).

The results obtained also indicated two interesting possible *theoretical limitations* to the developed approach. First, the effects of the interactive system on the link between expectations and emotional intensity appears to extend only to positive emotion (Table 4), and not to negative emotion (Table 5). This result is interesting because the feedback manipulations did enable the system to cause negative emotion and also determine its intensity (Figure 2c), but it did not lead people to think they did worse than expected in the manner that we intended (Figure 2a). Possibly, people are more willing to adjust their expectations when the

feedback manipulations are more positive than when they are negative, which may drive them to seek the cause of this suggested decline in creative task performance elsewhere, e.g. believing that the interactive system must be wrong [9].

Second, the effects of the system on the emotional intensity-creativity link appear to extend to positive (Table 6), but not to negative emotion (Table 7). This finding contradicts our assumption that the intensity of negative emotion subtracts from the flexibility necessary to generate original ideas as no such subtractive effect occurred in our study. It is possible that no such subtractive effect exists of negative emotion on flexibility. However, as discussed, the feedback manipulations intended to cause negative emotion, did not influence expectation (Figure 2a). Possibly, if the cause of negative emotions was attributed externally, such as to the aforementioned wrongful interactive system, then it is conceivable that this functions as a form of self-regulation that prevents the caused negative emotions from impacting the user's ability to generate original ideas [cf. 9]. One interesting consideration for theoretical future work is to investigate whether we can turn this limitation into an asset. That is, by deliberately increasing the likelihood that people attribute the cause of any negative feedback by the system externally, we can invoke self-regulation mechanisms in the user that prevent a user from being affected by their own inability to generate original ideas, and subsequently repair any consequential negative emotions that might further limit their momentary creative capabilities [cf. 10].

The interactive system developed and tested in this paper was specifically designed to investigate our hypotheses under laboratory conditions. It is nevertheless interesting to reflect on possible limitations, opportunities, and future work for the use our results in interactive systems that can be used to help support creativity in *practice*.

First, practical application will depend on the utility of providing computational feedback itself. Recent work shows that the appraisal of one's own ideas is typically executed poorly, with negative implications for creative task performance [e.g. 5]. This suggests that, at least for some people, providing feedback during ideation addresses a fundamental problem during idea generation, and can help to guide users during their idea generation process. Contrary to this, it is also popularly claimed that deferring judgment facilitates creativity during idea generation [e.g. 26]. This suggests that, perhaps for other people, providing feedback can interrupt idea generation, also with negative implications for creative task performance. Possibly, providing any feedback at all could be detrimental to creativity. We suggest that *user studies* can be an effective way to investigate if, how, and for whom, computational feedback itself can be an effective way to support creativity in practice.

Second, it is reasonable to assume that continued use of feedback manipulation may lead to a user discovering the systems' manipulations, possibly with negative effects on its believability and subsequently its utility. This requires a more technologically advanced approach than the one used in this experiment. Interestingly, we can find inspiration in recent advances in game technologies. In many computer games, the difficulty to achieve positive outcomes is varied adaptively, sparsely, and timed effectively in order to keep players engaged [31]. The appropriation of these technologies for feedback manipulation within the context of creativity support, can possibly help to sustain effectiveness over prolonged use. Therefore, we suggest that further *technological development* is necessary to develop interactive systems based on our results that can be used to support creativity in practice.

Third, if we assume that our findings can be generalized across different application domains, it is still likely that the way that the manipulated feedback is presented will need to be adapted to the context in which a creativity support tool is used. This may, for instance, depend on the features of the technology being used, ranging from basic mobile apps in which ideas can be stored [17], to fully interactive creative partners with which a user can interact socially. It may also need to be sensitive to *domain specific* needs, ranging from supporting a quick brainstorm at the office, to supporting creativity longer term in the development of an artistic process [22]. We suggest that our findings can potentially be integrated in a wide range of creativity support tools, but that this would require that we adapt the way the manipulated feedback is presented to the limitations and possibilities posed by the technology used, and the domain in which it is applied.

To summarise, the study discussed embodies one of the first steps toward a novel line of interactive technologies that aim to manipulate cognitive appraisals, as a way to intentionally cause emotion with an intended intensity, with the goal to help people to get more out of their own creative capabilities.

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