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.

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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 1). 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.

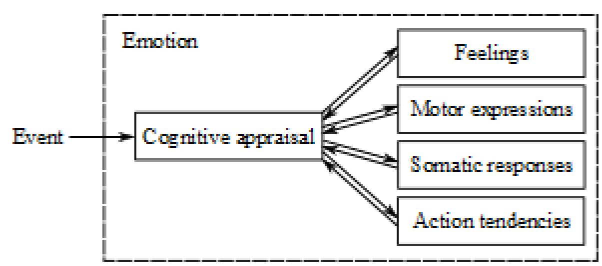

Figure 1 Appraisal-centered interpretation of emotion (after [26, 36]). Bi-directional arrows represent feedback relations among the emotion components.

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 1), 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.

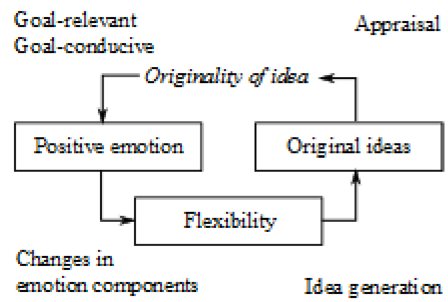

Figure 2 Impression of the hypothesized link between positive emotion, flexibility, and the generation of original ideas.

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 2), 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 1). 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 1 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 1). 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 2) 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.

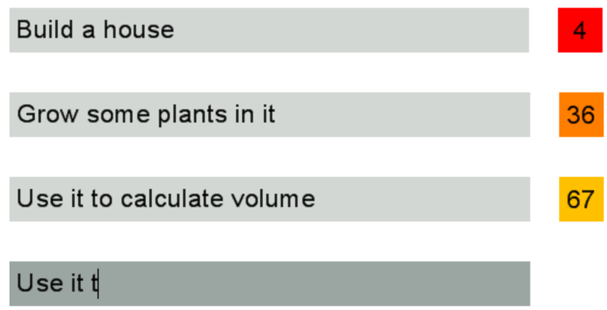

Figure 3 A screenshot of the way feedback is presented showing text entry (left), and feedback (right). The ideas and feedback shown here are responses to the brick as a subject, with the negative feedback manipulation.

Hypotheses

To put our theoretical conjectures and developed interactive system to the test, we experimentally test the following four hypotheses (Table 3).

#	**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 5. To test whether the feedback manipulations influenced originality, satisfaction, and frustration we performed LMM analysis on each of these variables individually (Table 6).

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 6), 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 7 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 7) represented the majority of variability. However, in all cases the variance for the random intercepts (participants) was significant as well (intercept, Table 7), 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 8 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, Table 8, 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, Table 8). 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, Table 8) 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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