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# E-Motioning: Effects of emotional generative visuals on creativity and connectedness during videoconferencing

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Videoconferencing has become an essential part of business life, and the trend of remote collaboration is set to continue in the future. However, research has shown that the lack of social cues in videoconferencing negatively impacts human social connectedness and hinders the production of creative ideas. Therefore, E-Motioning has been proposed as a system that generates geometrical-based visuals according to users' real-time emotions, and these visuals are used, as backgrounds for videoconferencing. An experiment was conducted with twenty-four participants to examine the effects of E-Motioning on creativity and connectedness in Microsoft Teams compared to a control condition that uses the actual physical environment as background. Quantitative and qualitative data were collected and analyzed. The results revealed that participants obtained a higher level of connectedness under the E-Motioning condition. However, there were no statistically significant differences in creativity between the two experimental groups. These findings have implications for future research and practice.

***Keywords: generative art; facial expression recognition; emotion visualization; videoconferencing***

## 1 Introduction

In recent years, videoconferencing has become an essential part of business life, especially due to the Corona pandemic (Sandhu et al., 2023). It enables people to maintain their social presence meaningfully in the online environment by allowing both audio and video, bringing convenience and cost savings (Archibald et al., 2019). Its flexibility also brings great value to people with different geographical locations when they need to collaborate and communicate (Credé & Sniezek, 2003). The number of users of videoconferencing applications is currently growing very rapidly (Patnaik, 2020) and the trend of remote collaboration is set to continue in the future (Druta et al., 2021).

Nevertheless, videoconferencing leads to a lack of face-to-face interaction that takes place in the same physical location, which makes users feel less connected (Kim et al., 2014), posing a risk to human social connectedness. Moreover, research shows that even though interactions in videoconferencing can convey the same information as the offline situation, there are still physical differences present that inhibit creativity and thus hinder idea generation (Brucks & Levav, 2022). Cukor et al. (1998) identified these differences as the interpersonal interaction information like facial expressions and body language, which are also nonverbal social cues conveying emotions (Adams et al., 2017). Those social cues bring important social and contextual information and contribute to social understanding during communication and interaction (Freeth et al., 2013).

Research has demonstrated the positive impact of natural virtual backgrounds on creativity in videoconferencing (Palanica & Fossat, 2022). However, this does not address the essence of the problem, which is the absence of nonverbal feedback (Kiesler et al., 1991) as one of the things missing in videoconferencing compared to physical interaction. Non-verbal cues can control, regulate and improve communication (Nemiro, 2016). Nemiro (2016) further suggested that if such feedback is missing, additional dimensions may be necessary to create connected, coordinated, and collaborative working environments for enhancing creativity.

This study investigates how the aforementioned factors could be improved from the perspective of missing social cues. Therefore, E-Motioning has been proposed as a system that generates geometrical-based visuals according to users' real-time emotions, and uses these visuals as backgrounds for videoconferencing. Emotions are detected through facial recognition and then categorized into three types: positive, negative, and neutral. The system conveys those detected emotions artistically, as metaphorical social cues that exist in the background. The abstract and random artistic visuals allow users to communicate their real-time emotional messages while promising to stimulate their creativity. The research question of this study is: what are the impacts on creativity and connectedness of introducing emotional generative visuals as meeting background in videoconferencing?

Based on the literature, in the following section, we hypothesize the following:

- H1. Visuals reflecting emotional states as a background for videoconferencing will positively influence an individual's social connectedness.
- H2. Presenting abstract artistic visuals that convey emotive information, as the videoconferencing background will increase an individual's creativity.

The rest of the paper is structured as follows. The design process is outlined in Section 3, while Section 4 describes the experimental methods employed. This is followed by Section 5, which presents the results. Section 6 offers a thorough discussion of the limitations of the study and presents recommendations for future work. Lastly, Section 7 presents the conclusions drawn from the study.

# 2 Literature review and hypotheses

## 2.1 Computational generative art

Generative art, also known as computer art, is an artistic field that has been inspired and developed by ideas about emergence, evolution, and self-organization, heavily relying on digital computing technologies, e.g., artificial intelligence and artificial life (Boden & Edmonds, 2009). Not all generative arts involve computers, but this study only examines computational generative art, specifically visual art.

McCormack and Dorin (2001) argued that generative art is framed by the manipulation of the artist, while Galanter (2003) proposed that the generative art process has an element of autonomy and operates independently of the artist. This leads to a consideration of the role of the human artist and the computer system in generative art. Contemporary generative art systems are based on mathematical equations, stochastic processes, deep learning, and other rule-based techniques, most of which focus on abstract visuals (Phon-Amnuaisuk & Panjapornpon, 2012). Examples of this include, but are not limited to: SBART2.4, an interactive tool that utilizes user feedback to control the creation of artifacts (Unemi, 2002); Processing, a programming environment using code-based approaches to generate art (Reas & Fry, 2006). In these examples, artists establish general rules for the system while also allowing the computer system to make some decisions.

From the perspective of the computer art community, the work is supposed to be generated by specific rules or constraints rather than by a sequential algorithm (Boden & Edmonds, 2009, p. 24), which has been taken as a central idea in the design process of this study. Accordingly, rules are crucial. When designing rule-driven generative art systems, the conscious decisions of the human artist should take precedence over system autonomy.

## 2.2 Emotion-related visualization

Visualization is not only a method of visual analysis but also a mediation of art (Viégas & Wattenberg, 2007). Emotion visualization is a useful tool that facilitates the identification and management of emotions, which allows individuals to more accurately perceive and comprehend their own emotions and the emotions of others (Koo et al., 2022; Lin et al., 2022). This can foster social interaction and enhance interpersonal understanding (Nummenmaa et al., 2012), which could contribute to a greater sense of social connectedness. Common low-level stimuli, such as color and picture composition, are well-used in computational modeling systems of emotions (Lu, et al., 2012). Hence, it is hypothesized that visuals reflecting emotional states as a background for videoconferencing will positively influence an individual's social connectedness (H1).

The greatest challenge of artistic visualization is to represent personal experiences of interacting with data (Manovich, 2002), as artistic mappings are often subjective and depend on the users' imagination and experiences (Krcadinac et al., 2015). Hanjalic (2016) argued that the expected emotional response could be considered objective, as it reflects a consistent response to a particular stimulus. However, emotions are ambiguous, imprecise, and culture-dependent (Krcadinac et al., 2015), indicating that there is no clear and standardized approach to interpreting the relationship between emotion and visuals. Designers, therefore, should anticipate and plan for the emotional reasoning of their target users by, for example, taking into account the cultural context (Brasseur, 2003, pp. 145-146).

### 2.2.1 Emotion classification

Emotions can be classified from two main perspectives: discrete and dimensional (Mauss & Robinson, 2009). The research from the discrete emotion perspective suggests that motions have different triggers, subjective experiences, and behaviors (Ekman, 1999; Panksepp, 1998). From the dimensional perspective, emotions are mostly considered from arousal and valence advocated by Russell (1980), where arousal refers to the intensity of the emotion from calmness to excitement; valence refers to the specific emotional content, labeled positive, negative, and neutral (Figure 1). This is described in the "Circumflex of Affect" (Russell, 1980).

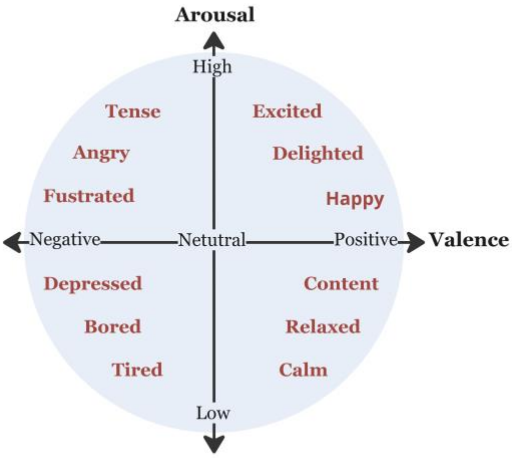



*Figure 1: Two-dimensional valence-arousal emotion, adapted from Russell (1980).*

In emotion recognition experiments, the dimensional model is more widely used due to the capability of locating discrete emotions in the two-dimensional plane, even if the emotion cannot be specifically defined (Liu et al., 2010; Mauss & Robinson, 2009). Watson (2000) stated that the dimensional perspective is sufficient enough to capture the essence of a particular emotional state and that it should be prioritized because it is highly parsimonious.

### 2.3 Effects of visual stimuli on creativity

Visual stimuli have been commonly employed for problem-solving and innovation in creativity research. It has been suggested that abstract concepts through visual stimuli can increase the chances of producing original ideas by providing a suitable level of structure and allowing for sufficient exploration (Baughman & Mumford, 1995; Ward et al., 2004). Research by Malaga (2000) supports the effectiveness of visual stimuli in stimulating creative ideas compared to text-based stimuli. Furthermore, Casakin (2005) found that a diverse range of visual representations can aid both students and expert architects in solving complex problems. Overall, visual stimuli can positively influence creativity in various contexts. Besides that, emotional cues can improve cognitive flexibility, which can lead to better creativity (Xu et al., 2022), by enhancing attention, exploration of alternative actions, and flexible information processing (Baas et al., 2008; Schwarz & Bless, 1991; Schwarz, 2002). Therefore, it is hypothesized that presenting abstract artistic visuals that convey emotive information, as the videoconferencing background will increase an individual's creativity (H2).

## 3 Design

### 3.1 Visualization design

The selection and development of emotional-related visual features is a challenge as different research purposes and fields require different features for the task at hand (Machajdik & Hanbury, 2010). The creation of emotional visualizations in this study began by examining theories about the connection between psychology, art, and the emotional effects of color and shape. The key features were identified through a combination of considerations and insights from a user study, which was conducted to modify and refine certain features to fit the specific characteristics and objectives of this study.

### 3.1.1 Classification of emotional categories

The emotion classification followed Ekman's six basic emotions (Ekman & Friesen, 1971; Ekman et al., 1969) with some adjustments. To address privacy concerns and the fact that there is no one-fits-all solution for mapping visuals to emotions, the emotions were classified as positive, neutral, or negative. "Surprise" was excluded from the system as it can have any valence. This decision was in line with Clore and Ortony's (2013) view that emotions are affective reactions to things being good or bad. The remaining five emotions were further categorized, with "happiness" as positive, "sadness", "anger", "disgust" and "fear" as negative. Additionally, "neutral" was added.

### 3.1.2 Visual feature extraction

Color is one of the most extensively researched visual elements when it comes to emotional analysis. However, associating emotions with colors can be problematic due to subjectivity and the influence of cultural and anthropological contexts (Colombo et al., 1999; Itten, 1973). This study followed the emotion-color mappings established by de Pos and Green-Armytage (2007), who examined how people of various ages and cultural backgrounds relate colors to Ekman's basic emotions. Participants in their study were asked to select color samples and associate them with facial expressions for each emotion type. The results showed that the emotion of happiness is associated with light colors, while negative emotions tend to be associated with darker colors. Based on this knowledge, the palette from da Pos and Green-Armytage (2017) has been chosen to set the preliminary color features, with adjustments based on the findings of Kawai et al. (2022) to avoid culturally dependent colors such as red. The participants in Kawai et al.'s (2022) cross-cultural study of color-emotion associations were Chinese and Western (Austrian/German), which was particularly relevant to the subjects of this study.

In terms of the relationship between emotions and shapes, research has demonstrated the importance of shapes and geometric properties in comprehending emotions. Geometric-based visuals can convey emotions such as anger and happiness (Aronoff, 2006; Reber et al., 2004). According to Bar and Neta (2006), sharp shifts in contour lines convey a sense of threat and result in negative bias, whereas curved contour lines promote positive emotions. Specifically, circles are associated with positive emotions, while triangles are seen as conveying negative emotions (Aronoff et al., 1992; Larson et al., 2011). Moreover, rectangles represent logic, order, and homogeneity (Kim, 2017; Pinna, 2012), which have been chosen to represent neutral emotion at this stage. As a result, the preliminary emotion visual mapping was summarized in Table 1, which has been used to select the generated images to present to the respondents.

*Table 1. Temporary features to emotions, where green and grey have been chosen as transitional colors to bridge the colors*

| **Emotion** | **Shape** | **Color** |
|---|---|---|
| Positive | Circle | Orange<br>Yellow |
| Neutral | Square | Green<br>Blue |
| Negative | Triangle/Line | Grey<br>Black |

## 3.2 Visual evaluation

Twelve images represented one of the three emotion categories were presented to respondents in a random order to verify the relationship between the proposed shape, color features, and the emotions they represent. Respondents were asked to select three images that best represented positive, neutral, or negative emotions, respectively. Besides that, they also completed a survey asking for colors, shapes, and other possible parameters that could represent or relate to their emotion visualization with the reasoning. The survey aimed to uncover other potentially relevant features that were not depicted in the example images.

### 3.2.1 Respondents

A total of twenty-two respondents participated in the visual evaluation, comprised of ten males, eleven females, and one non-binary, aged 19-55 years, with a mean (M) ± standard deviation (SD) age 28.2 ± 12.02. The respondents were students (bachelor and master) and employees (Ph.D. candidates and teachers) from the Industrial Design (ID) department at the Eindhoven University of Technology (TU/e), with the majority coming from the Netherlands (14) and China (6). Respondents had similar characteristics to the final experimental participants' sample, but they were not part of the sample pool.

### 3.2.2 Data analysis & results

The responses showed that orange/yellow with circles was the most commonly chosen to represent positive emotions, while black with triangles for negative emotions. Specifically, 72% and 68% of respondents chose example images that matched these feature combinations, respectively. However, there was a wide range of choices for "neutral emotions" with some respondents not selecting any images. This can be explained by the fact that 50% of respondents chose white as the color that represents neutral emotions, which was out of the temporary color feature range previously identified.

Furthermore, respondents' perceptions of the visual contents were noted. For instance, I3 (circle + green) was intended to show neutral emotion, but 36% of the respondents perceived it as positive because "It's shaped like the sun" and "Looks like a blooming flower". The generative visuals in this study were based on abstract geometric shapes, but some may inevitably have implied semantic content. Additionally, the interpretation of the image content may be influenced by the experience of inter-individual differences when processing abstract ambiguous images, called "pareidolia" (Petchkovsky, 2008). Overall, the final feature classifiers built for each emotion are as follows.

*Table 2. Key features of emotions*

| Emotion | Features | | |
|---|---|---|---|
| | **Shape** | **Canvas Color** | **Line Color** |
| Positive | Circle | Yellow | Orange |
| Neutral | Line | White | Blue/Green |
| Negative | Triangle | Black | White |

## 3.3 E-Motioning

The E-Motioning system consists of three main parts, as illustrated in Figure 2. This section describes each of them in detail.

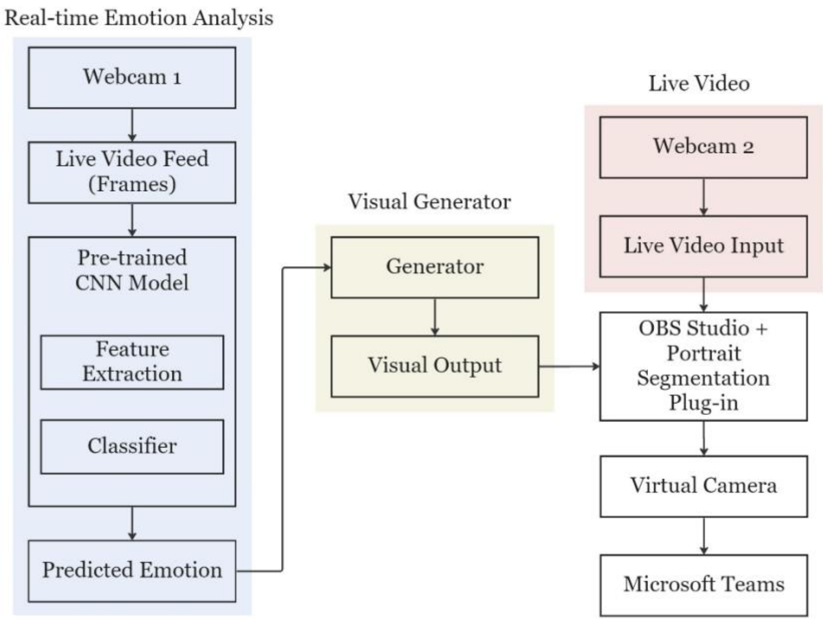



*Figure 2: The architecture of the E-Motioning system.*

### 3.3.1 Facial emotion recognition

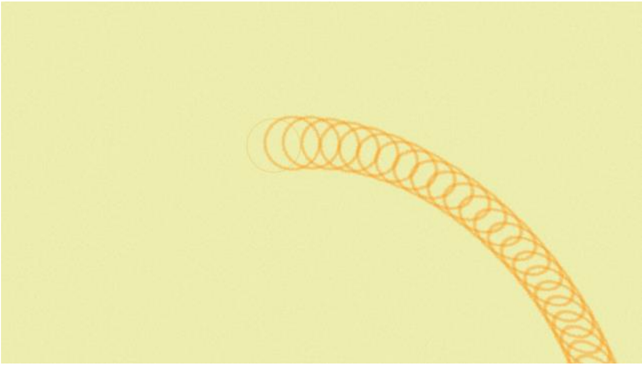
Convolutional Neural Network (CNN) was used for facial emotion recognition in the E-Motioning system in order to determine participants' emotions from the webcam input. The used model is capable of recognizing Ekman's six basic emotions (Ekman & Friesen, 1971; Ekman et al., 1969), which was adapted from the work of Bhattiprolu (2021) and used for real-time emotion detection. It was used to detect the emotion of all faces every 20 seconds during the experiment.

It was trained on a public dataset created by Carrier and Courville (2013), where each face was assigned a corresponding emotion by human labelers (Goodfellow et al., 2013). Specifically, this dataset contains 35887 images (with 13.8% of anger, 1.5% of disgust, 14.3% of fear, 25.0% of happiness, 16.9% of sadness, 11.2% of surprise, and 17.3% neutral). They have been further divided into positive (28.2%), neutral (19.5%), and negative (52.3%) categories, with surprise excluded and anger, disgust, fear, and sadness classified as negative. Note that 80% of the images have been used for training and 20% for testing. The used model has been trained up to 200 epochs, achieving an accuracy of 80%.

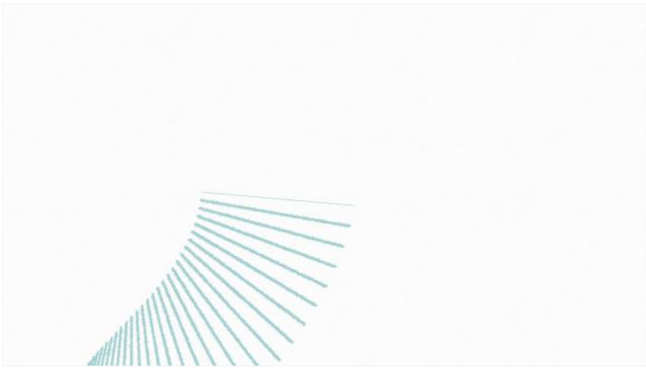
### 3.3.2 Generative visuals

The generative visuals algorithm is built upon the work from Doersing (2022) and implemented in Python. The shape feature is controlled by three subclasses: circle, triangle, and line. The canvas color and line color are both determined by three parameters: red, green, and blue (RGB). In addition to these emotion-related features, the algorithm includes other features such as canvas noise and line opacity that control the behavior of the iterative drawing routines and generate random values to produce a unique visual output each time. These features were each set to an appropriate range of parameter values to avoid dimensional issues and generate aesthetically appealing visuals that incorporate emotional content. The generated visual is saved as a PNG image, and if a new visual is generated, it will replace the previous one.

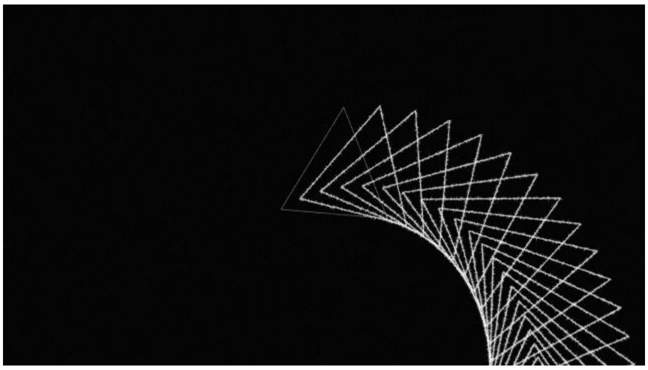
Additionally, the output is determined by the emotion prediction results. Only when the input emotion varies, the system will generate a new visual in response, otherwise, it remains the same visual.



(*a)*



(*b)*



*(c)*

*Figure 3: Examples of visuals generated by E-Motioning representing three emotional types: (a) positive; (b) neutral; (c) negative.*

### 3.3.3 Integration with videoconferencing

Microsoft Teams was selected as the videoconferencing platform of reference. Open Broadcaster Software (OBS) Studio was used to create a virtual camera comprised of multiple sources organized into one scene. OBS enabled the live video of the participant to be overlaid on top of the generative visual source and displayed as a virtual camera which Microsoft Teams uses as input. A fade transition was applied to the visual source to facilitate a smooth transition between changing visuals.

In Microsoft Teams, the videos for both participants and the experimental assistant (EA) were pinned to ensure that the total screen area and visual attention devoted to the background stimuli were equal, as shown in Figure 4. This was done by right-clicking the video and selecting the “pin” option.

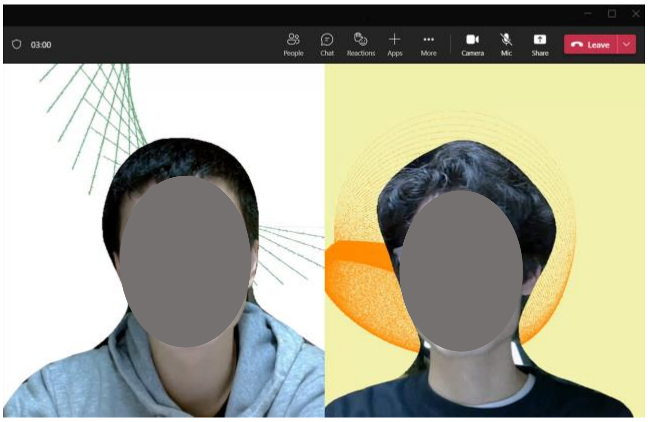



*Figure 4: Presentation of E-Motioning in Microsoft Teams.*

# 4 Methods

## 4.1 Participants

Purposive sampling was employed to select participants in the experimental and control groups based on three criteria: prior experience with videoconferencing, (corrected to) normal vision, and residence in the Netherlands or China. The last criterion was implemented to maintain consistency with the background of the respondents participating in the visual evaluation. This study was approved by the Ethical Review Board of the Eindhoven University of Technology (TU/e).

In total, twenty-seven master’s students (M ± SD age 24.3 ± 1.46) from TU/e participated. A pilot study involving three participants was conducted to evaluate and improve the validity and feasibility of the experimental design, the results of which were not included in the final data analysis.

Therefore, the final data analysis was based solely on the results of the formal experiment, which included a sample of twenty-four participants (M ± SD age 24.3 ± 1.49). Their basic demographic information is concluded as follows:

*Table 3. Demographic information of the participants*

| | | **Number** |
|---|---|---|
| **Age** | 21-23 | 7 |
| | 24-26 | 15 |
| | 27-30 | 2 |
| **Gender** | Male | 12 |
| | Female | 12 |
| **County** | the Netherlands | 11 |
| | China | 13 |
| **Major** | Industrial Design | 19 |
| | Industrial Engineering & Innovation Sciences | 5 |

## 4.2 Stimuli

The participants were randomly assigned to one of two between-subject conditions: control (n = 14) or E-Motioning (n = 14) as the control and experimental group, respectively. In the control condition, the participants' videoconferencing background was the actual physical environment they were in. In the E-Motioning condition, the background was the visual generated by the E-Motioning system (Figure 4).

This study utilized brain teaser questions as videoconferencing content to evoke participants' different emotions. This approach was based on the findings of Aliyari et al. (2021) demonstrating the positive effects of brain teaser games on the central nervous system as well as their ability to stimulate stress pathways leading to changes in various emotional signals, which mainly attributed to time limits. In both study conditions, participants were asked brain teaser questions by the EA and given a time limit of one minute to provide their answers verbally to each question. A total of twelve questions were prepared with the aim of provoking a sense of accomplishment and satisfaction when participants arrived at the correct answer; the order of the questions was randomized. In addition, the questions were designed to provide some comedic relief as participants may encounter very simple problems that require creative thinking. For example, one question was "In a year, there are 12 months. Seven months have 31 days. How many months have 28 days?", the correct answer is: "They all do". The actual number of questions asked varied according to the speed of the participant's response.

To elicit a broader spectrum of emotions, including neutral and negative emotions, the EA also provided verbal countdown reminders of thirty seconds and fifteen seconds remaining, potentially adding an element of pressure. By deliberately incorporating both brain teasers and countdown reminders, the study strived to achieve a more realistic distribution of emotional responses during the videoconferencing sessions.

## 4.3 Measures

The study used the Alternative Uses Test (AUT) (Guildford, 1967) to evaluate participants' creativity and the Inclusion of Other in the Self (IOS) Scale (Aron et al., 1992) to measure participants' level of connectedness. Additionally, a post-questionnaire was administered to gather qualitative feedback from the experimental group.

### 4.3.1 The Alternative User Test

The AUT, proposed by Guildford (1967), is a highly used test worldwide to measure an individual's creativity in divergent thinking (Chermahini et al., 2012; Lewis & Lovatt, 2013; Oppezzo & Schwartz, 2014; Palanica & Fossat, 2022). It requires participants to provide alternative uses for a common object, such as a pen, shoe, or cup, as much as possible in a limited amount of time (Abraham, 2018).

The results were evaluated from four components: originality, flexibility, fluency, and elaboration (Chermahini et al., 2012). Originality was determined by the rarity of responses to the overall dataset, with participants receiving 1 point for the response that was given by fewer than 5% of the total sample and 0 points for all others (Milgram & Milgram, 1976). The categories of responses were used to measure flexibility (Alhashim et al., 2020; Palanica & Fossat, 2022). The score of fluency refers to the number of responses given to the object (Alhashim et al., 2020; Guilford et al., 1978). Elaboration was determined by the level of detail in each idea, calculated as the total words of all responses per person (Alhashim et al., 2020).

### 4.3.2 The Inclusion of Other in the Self scale

The IOS scale, developed by social psychologists Aron et al. (1992), is a seven-point interval-level measure of an individual's perceived sense of interconnectedness with another person (p. 602), which was used to evaluate the level of connectedness of the participant with the EA in this study. Participants were asked to choose the picture (Figure 5) that most accurately described their relationship with the experimental partner by answering the question, "Which picture best describes your relationship with your partner during the experiment?"

The IOS scale has been demonstrated applicability to various and valid measure of subjective closeness in relationships, with demonstrated applicability to various samples (Gächter et al., 2015).

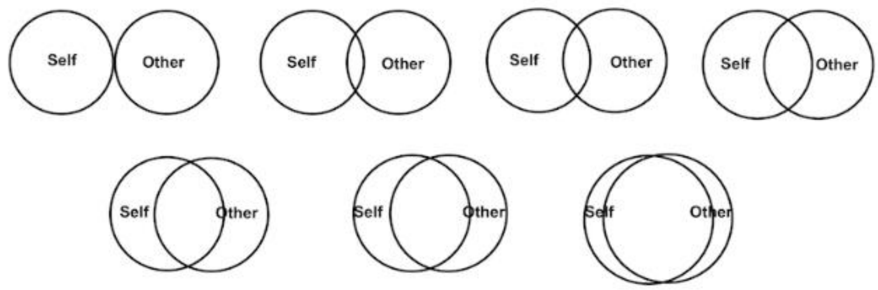



*Figure 5: The IOS scale, where 1=no overlap; 2=little overlap; 3=some overlap; 4=equal overlap; 5=strong overlap; 6=very strong overlap; 7=most overlap (Gächter et al., 2015).*

### 4.3.3 The Post-Questionnaire

The post-questionnaire consisted of six questions, including two related to the level of understanding of the E-Motioning system and suggestions for future development, two questions to assess user acceptance, and two open-ended questions to solicit other feedback.

## 4.4 Procedure

Each participant was connected to the EA via Microsoft Team's one-on-one videoconferencing interface in separate rooms. Before the experiment, they were thoroughly briefed on the purpose and procedures and were provided with a printed consent form. They were asked to sign the form digitally, and provide their demographic information.

During the videoconferencing, participants engaged in a conversation with the EA, during which they were required to answer brain teaser questions. The conversation lasted for fifteen minutes. Subsequently, they had two minutes to perform an AUT, listing as many alternative uses for a shoe as possible. Following the AUT, they were asked about their familiarity with the brain teaser questions in the experiment (on a scale of 1 = not familiar to 5 = very familiar).

At the end of the experiment, both control and experimental groups were requested to respond to the IOS scale. The experimental group was also invited to fill out the post-questionnaire, to provide valuable qualitative feedback on their overall experience with the E-Motioning system.

## 4.5 Data analysis

The quantitative data collected from the questionnaires were imported to Microsoft Excel and analyzed using SPSS® Statistics 27. Creativity-related data were first manually coded and processed into quantitative data. Additionally, the qualitative data were manually coded and organized into various themes to gain insights into the research question.

# 5 Results

## 5.1 Creativity results

The mean and standard error of originality, flexibility, fluency, and elaboration were calculated and are displayed in Figure 6.

The results of the one-way analysis of variance (one-way ANOVA) showed that in all cases, the p-value was greater than 0.05, indicating that there was no significant in originality, flexibility, fluency, or elaboration between the control and E-Motioning groups. Therefore, no conclusions can be drawn from the AUT with respect to creativity, which failed to provide support for hypothesis H2.

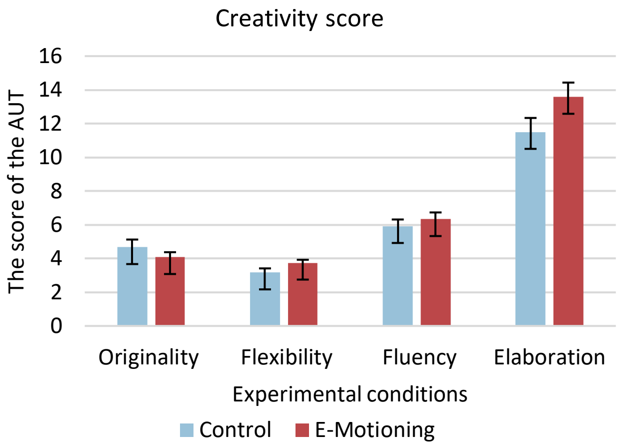



*Figure 6: Scores for the four components of creativity in the two study conditions (displayed with standard error bars).*

## 5.2 Connectedness

A one-way ANOVA was conducted to compare the mean values of control and E-Motioning conditions as within-subject factors. The resulting p-value of 0.014 < 0.05 indicated a significant difference in the connectedness mean score between the control and experimental groups. Specifically, the mean score in the E-Motioning condition (M = 5.75, SD = 0.97) was significantly higher than it was in the control condition (M = 4.75, SD = 0.87), which confirmed hypothesis H1.

According to the results of the quantitative effect analysis, the Eta square ($\eta^2$ value) of Score was found to be 0.245, indicating that 24.5% of the data differences were attributed to differences between the various groups. Additionally, Cohen's f value was 0.569, signaling a substantial degree of difference in the quantified impact of the data.

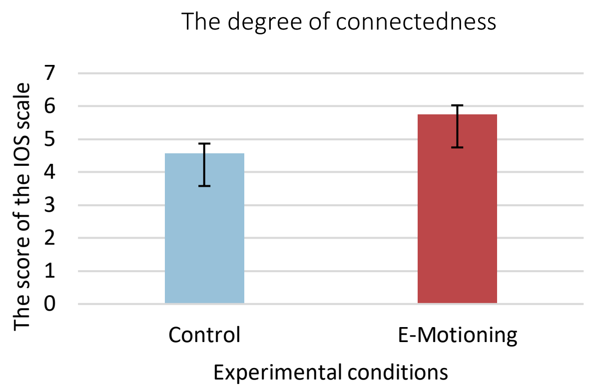



*Figure 7: The mean differences and standard errors of the level of connectedness, measured by the IOS scale (displayed with standard error bars).*

## 5.3 Analysis of variance

To investigate the impact of participants' prior knowledge of the brain teaser question (M = 3.1, SD = 0.68) on their mean scores of the IOS scale and the AUT, a one-way ANOVA was performed. The result (p = 0.655 > 0.05) showed that participants' familiarity with the brain teaser questions did not significantly affect the mean differences between the control and experimental groups. Thus, it can be concluded that the differences were likely caused by the experimental conditions.

## 5.4 Potential customer acceptance

E-Motioning gained a high level of interest among the participants in regard to future use, suggesting its significant potential. When asked if they would use the system in the future and why, nine out of twelve participants (75%) answered in the affirmative, while three participants (25%) answered no. Participants who answered "yes" generally reported that E-Motioning assisted them in effectively communicating their emotions and more intuitively understanding the emotions of others. They also found the artistic expression aspect of E-Motioning to be enjoyable. Participant 2 further stated, "for games with friends, would be fun."

Participant 3 mentioned that the background feature would be distracting, while Participant 6 stated that a more seamless transition between emotional backgrounds would be preferable. Both participants' responses highlighted potential areas for improvement in the system design. Participant 10 expressed reluctance towards using the system, stating that he did not see a reason for employing it in a professional setting unless it was for the purpose of amplifying emotions during online calls. This comment suggested a need for further consideration of the specific application scenarios for the system.

Overall, the system received an average score of 7.8 out of 10, suggesting that the participants had a favorable impression of E-Motioning. The SD was 1.21, indicating a relatively consistent level of fondness among the participants. All participants in the experimental group also noted the high level of privacy protection offered by the E-Motioning system.

## 5.5 Insights into the E-Motioning system

### 5.5.1 Understanding of the E-Motioning system

It appears that participants had varying levels of understanding of the E-Motioning system. 75% of participants reported a good understanding of the mapping of the generative visuals to emotions and were also able to effectively understand their own emotions and the emotions of others through the visuals. Others (25%) had difficulty understanding certain aspects of the system. For example, Participant 6 expressed confusion about the difference between neutral and positive emotions, suggesting further clarification or explanation of neutral and positive. It is also worth noting that Participant 10 who answered "partly understood" stated, "I did pay attention to my emotions during the experiment, so I was confused when the visuals changed."

### 5.5.2 Recommendations for the E-Motioning system

The suggestions provided by the participants for improving the E-Motioning system focused on both the system itself and the application scenarios. The first concerned visual improvements such as a larger background screen and additional features to distinguish between positive and negative emotions, which could enhance the user experience and reduce confusion. Making the dynamic visual dynamic or incorporating the natural landscape was also suggested as a way to increase the enjoyment of the system. Moreover, Participant 10 suggested using better devices to improve the accuracy of emotion detection and adding other message cues, as the current system "does not convey any new information". Participants 2 and 22 recommended testing the system in group settings or simulated social situations to gain a better understanding of its performance in real-world scenarios.

# 6 Discussion

The present study aimed to examine the effects of E-Motioning, a system that generates geometrical-based visuals according to users' real-time emotions as social cues, on creativity and connectedness in videoconferencing. A total of twenty-four participants participated in the formal experiment under two conditions: control and E-Motioning. Both quantitative and qualitative data were collected and analyzed.

The results of this study suggest that E-Motioning may be effective in improving social connectedness in videoconferencing. Participants under the E-Motioning condition reported higher levels of connectedness compared to those in the control group, which aligns with previous research on the impact of nonverbal cues on social connectedness (Freeth et al., 2013). However, no statistically significant differences were found in terms of creativity between the two groups. It is plausible that the E-Motioning system, despite its potential to evoke emotions and enhance connectedness, might not have been specifically designed to stimulate creative thinking. The absence of targeted features or cues aimed at fostering creativity might have contributed to these results. More factors have been discussed in 6.1.

The qualitative data also highlighted some interesting findings. Although participants' understanding of the E-Motioning system was mixed, suggesting that further clarification and explanation may be needed to improve the user experience, E-Motioning was generally well received by participants and gained good potential customer acceptance. In addition, participants made several recommendations for improving the E-Motioning system, including visual improvements, better devices for emotion detection, and testing the system in group settings with real social scenarios. These recommendations could be useful for future development and testing of E-Motioning.

### 6.1 Limitations and future work

This study has limitations that may serve as a foundation for future research. The small sample size is not representative of the larger population, which may limit the validity and generalizability of the results. Additionally, the short duration of the videoconferencing time (fifteen minutes) may not have allowed enough time for participants to fully engage with E-Motioning and produce valid creative ideas in the AUT. The use of a simple creative task without preparation or incubation time may have also influenced the outcomes. Future research could consider using longer experimental sessions to fully examine the effects of E-Motioning on creativity and connectedness over time and taking into account individual differences in intrinsic creative abilities before the experiment.

It is also essential to recognize the limitations of the creativity assessment tool used in this study. While the AUT is a well-established measure of divergent thinking, it might not fully capture the complex and multifaceted nature of creativity. Future research may consider incorporating additional measures, such as creative problem-solving tasks or domain-specific creativity assessments, to comprehensively explore the impact of the E-Motioning system on creativity.

Furthermore, the process of quantifying the results of the AUT, i.e. coding, also has limitations. Using the researcher as a coder introduces the risk of bias. Moreover, the two coders were not uniformly trained so the consistency of coding is not entirely reliable. One way to mitigate this would be to provide uniform training to all coders to ensure consistency in the coding process. Alternatively, using unsupervised machine learning to code could be an option as it is not influenced by subjective human judgment.

Lastly, the experimental content was designed to stimulate a range of emotions to better interact with E-Motioning. However, this may not accurately reflect the range of emotions and reactions experienced in real-world videoconferencing situations. Future research could investigate the effects of E-Motioning in more naturalistic videoconferencing scenarios, such as by using more realistic meeting tasks. This would help to better examine the impact of E-Motioning in more representative contexts.

## 7 Conclusion

This study has introduced the E-Motioning system, which generates abstract visuals as social cues based on real-time emotions. The mapping of emotions to visuals was developed through a user study, and the results were supported by the subsequent experiment. The experiment found that the use of emotional generative visuals as meeting backgrounds in videoconferencing can have a positive impact on social connectedness, but did not have a significant effect on creativity. Despite this, this study has added to the understanding of the powerful impact of emotional visualization and provides a guiding direction for future research in real-world settings, such as online education and work-from-home settings. It is worth noting that the generalizability of these findings may be limited due to the specific research design and the sample of this study. Further research is needed. However, the positive attitude and interest expressed by the participants suggest that the E-Motioning system has the potential for customer acceptance. Overall, this study has contributed valuable insights into the fields of computer art and emotion-related visualization. Its findings have important implications for the use of emotional generative visuals in videoconferencing settings.

## References


Abraham, A. (2018). The Neuroscience of Creativity. Cambridge: Cambridge University.

Achlioptas, P., Ovsjanikov, M., Haydarov, K., Elhoseiny, M., & Guibas, L. (2021). ArtEmis: Affective Language for Visual Art. ArXiv: Computer Vision and Pattern Recognition. Retrieved from https://arxiv.org/pdf/2101.07396.pdf

Adams, R. B., Albohn, D. N., & Kveraga, K. (2017). Social Vision: Applying a Social-Functional Approach to Face and Expression Perception. Current Directions in Psychological Science, 26(3), 243–248. doi:10.1177/0963721417706392

Alhashim, A. G., Marshall, M., Hartog, T., Jonczyk, R., Dickson, D., van Hell, J., . . . Siddique, Z. (2020). WIP: Assessing creativity of alternative uses task responses: A detailed procedure. 2020 ASEE Virtual Annual Conference. ASEE Annual Conference and Exposition, Conference Proceedings.

Aliyari, H., Sahraei, H., Golabi, S., Kazemi, M., Daliri, M. R., & Minaei-Bidgoli , B. (2021). The Effect of Brain Teaser Games on the Attention of Players Based on Hormonal and Brain Signals Changes. Basic and clinical neuroscience, 12(5), 587–596. doi:10.32598/bcn.2021.724.9

Archibald, M. M., Ambagtsheer, R. C., Casey, M. G., & Lawless, M. (2019). Using Zoom Videoconferencing for Qualitative Data Collection: Perceptions and Experiences of Researchers and Participants. International Journal of Qualitative Methods, 18. doi:10.1177/1609406919874596

Aron, A., Aron, E., & Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. Journal of Personality and Social Psychology, 63(4), 596–612. doi:10.1037/0022-3514.63.4.596

Aronoff, J. (2006). How we recognize angry and happy emotion in people, places, and things. Cross-Cultural Research, 40(1), 83-105. doi:10.1177/1069397105282597

Aronoff, J., Woike, B. A., & Hyman, L. M. (1992). Which are the stimuli in facial displays of anger and happiness? Configurational bases of emotion recognition. Journal of Personality and Social Psychology, 62(6), 1050–1066. doi:10.1037/0022-3514.62.6.1050

Baas, M., De Dreu, C. K., & Nijstad, B. A. (2008). A meta-analysis of 25 years of mood-creativity research: Hedonic tone, activation, or regulatory focus? Psychological Bulletin, 134(6), 779-806. doi:10.1037/a0012815

Bar, M., & Neta, M. (2006). Humans Prefer Curved Visual Objects. Association for Psychological Science, 17(8), 645–648. doi:10.1111/j.1467-9280.2006.01759.x

Baughman, W. A., & Mumford, M. D. (1995). Process-analytic models of creative capacities: Operations influencing the combination-and-reorganization process. Creativity Research Journal, 8(1), 37-62. doi:10.1207/s15326934crj0801_4

Bhattiprolu, S. (2021, October). 239_train_emotion_detection.py [Software-code]. Github. Retrieved October 2, 2022, from https://github.com/bnsreenu/python_for_microscopists/blob/master/239_train_emotion_detection/239_train_emotion_detection.py

Boden, M. A., & Edmonds, E. A. (2009). What is generative art? Digital Creativity, 20(1-2), 21-46. doi:10.1080/14626260902867915

Brasseur, L. E. (2003). Visualizing Technical Information: A Cultural Critique. NY: Bay Press.

Car-rier, P. & Courville, A. (2013). Facial Expression Recognition 2013 [Dataset]. https://www.kaggle.com/c/challenges-in-representation-learning-facial-expression-recognition-challenge/data

Casakin, H. (2005). Design aided by visual displays: A cognitive approach. The Journal of Architectural and Planning Research, 22(3), 250–265.

Chermahini, S. A., Hickendorff, M., & Hommel, B. (2012). Development and validity of a Dutch version of the Remote Associates Task: An item-response theory approach. Thinking Skills and Creativity, 7(3), 177–186. doi:10.1016/j.tsc.2012.02.003

Clore, G. L., & Ortony, A. (2013). Psychological Construction in the OCC Model of Emotion. Emotion review : journal of the International Society for Research on Emotion, 5(4), 335–343. doi:10.1177/1754073913489751

Cohn, J. F., & Ekman, P. (2005). Measuring facial action by manual coding, facial EMG, and automatic facial image analysis. In J. A. Harrigan, R. Rosenthal, & K. R. Scherer (Eds.), The new handbook of nonverbal behavior research (pp. 9-64). New York: Oxford University Press.

Colombo, C., Bimbo, A. D., & Pala, P. (1999). Semantics in visual information retrieval. IEEE MultiMedia, 6(3), 38-53. doi:10.1109/93.790610

Credé, M., & Sniezek, J. A. (2003). Group judgment processes and outcomes in video-conferencing versus face-to-face groups. International Journal of Human-Computer Studies, 59(6), 875-897. doi:10.1016/j.ijhcs.2003.07.001

Cukor, P., Baer, L., Willis, B., Leahy, L., O'Laughlen, J., & Murphy, M. (1998). Use of videophones and low-cost standard telephone lines to provide a social presence in telepsychiatry. Telemedicine Journal, 4(4), 313-321. doi:10.1089/tmj.1.1998.4.313

da Pos, O., & Green-Armytage, P. (2017). Facial Expressions, Colours and Basic Emotions. Colour: Design & Creativity, 1, 1-20.

Darwin, C. (1965). The expressions of the emotions in man and animals. Chicago: University of Chicago Press.

Doersing, N. (2022). A minimalist generative art thing [Source code]. https://github.com/doersino/uji

Druta, R., Druta, C., Negirla, P., & Silea, I. (2021). A Review on Methods and Systems for Remote Collaboration. Applied Sciences, 11(21), 10035. doi:10.3390/app112110035

Ekman, P. (1999). Basic Emotions. In M. D. Robinson, E. R. Watkins, & E. Harmon-Jones (Eds.), Handbook of Cognition and Emotion (pp. 45-60). New York: Wiley. doi:10.1002/0470013494.ch3

Ekman, P., & Friesen, W. V. (1971). Constants across cultures in the face and emotion. Journal of Personality and Social Psychology, 17(2), 124–129. doi:10.1037/h0030377

Ekman, P., & Friesen, W. V. (1978). Facial action coding system: A technique for the measurement of facial movement. Environmental Psychology & Nonverbal Behavior. doi:10.1037/t27734-000

Ekman, P., Friesen, W. V., & Hager, J. C. (2002). Facial action coding system: The manual on CD-ROM. Salt Lake City, UT: Research Nexus.

Ekman, P., Sorenson, E. R., & Friesen, W. V. (1969). Pan-Cultural Elements in Facial Displays of Emotion. Science. Science, 164(3875), 86-88. doi:10.1126/science.164.3875.86

Freeth, M., Foulsham, T., & Kingstone, A. (2013). What Affects Social Attention? Social Presence, Eye Contact and Autistic Traits. PLoS ONE, 8(1), e53286. doi:10.1371/journal.pone.0053286

Gächter, S., Starmer, C., & Tufano, F. (2015). Measuring the Closeness of Relationships: AComprehensive Evaluation of the 'Inclusionof the Other in the Self' Scale. PLoS ONE, 10(6), e0129478. doi:10.1371/journal.pone.0129478

Goodfellow, I., Erhan, D., Carrier, P. L., Courville, A., Mirza, M., Hamner, B., . . . Bengio, Y. (2013). Challenges in Representation Learning: A Report on Three Machine Learning Contests. Neural networks: the official journal of the International Neural Network Society, 64. doi:10.1016/j.neunet.2014.09.005

Guilford, J. P. (1976). The nature of human intelligence. McGraw-Hill.

Guilford, J. P., Christensen, P. R., Merrifield, P. R., & Wilson, R. C. (1978). Alternate uses: Manual of instructions and interpretations. Beverly Hills, CA: Sheridan Psychological Services.

Hamma, J., Kohler, C. G., Gur, R. C., & Verma, R. (2011). Automated Facial Action Coding System for dynamic analysis of facial expressions in neuropsychiatric disorders. Journal of Neuroscience Methods, 200(2), 237-256. doi:10.1016/j.jneumeth.2011.06.023

Hanjalic, A. (2006). Extracting moods from pictures and sounds: towards truly personalized TV. IEEE Signal Processing Magazine, 23(2), 90-100. doi:10.1109/msp.2006.1621452

Itten, J. (1973). The Art of Color: The Subjective Experience and Objective Rationale of Color. New York: John Wiley.

Kawai, C., Zhang, Y., Lukács, G., Chu, W., Zheng, C., Gao, C., . . . Ansorge, U. (2022). The good, the bad, and the red: implicit color-valence associations across cultures. Psychological Research. doi:10.1007/s00426-022-01697-5

Kiesler, S., Siegel, J., & McGuire, T. (1991). Social aspects of computer-mediated communication. In C. Dunlop, & R. Kling (Eds.), Computerization and controversy: Value conflicts and social choices (pp. 330-349). Boston, MA: Harcourt Brace.

Kim, K. J. (2017). Shape and Size Matter for Smartwatches: Effects of Screen Shape, Screen Size, and Presentation Mode in Wearable Communication. Journal of Computer-Mediated Communication, 22(3), 124-140. doi:10.1111/jcc4.12186

Kim, S., Lee, G., Sakata, N., & Billinghurst, M. (2014). Improving co-presence with augmented visual communication cues for sharing experience through video conference. 2014 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 83-92. doi:10.1109/ISMAR.2014.6948412.

Koo, D., O'Neill, T. C., Dinçer, S. B., Kwok, H. K., & Renelus, F. (2022). Immersive Emotions: Translating Emotions Into Visualization. In Adjunct Publication of the 24th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '22). New York: Association for Computing Machinery. doi:10.1145/3528575.3551430

Krcadinac, U., Jovanovic, J., Devedzic, V., & Pasquier, P. (2015). Textual Affect Communication and Evocation Using Abstract Generative Visuals. IEEE Transactions on Human-Machine Systems, 46(3), 370 - 379. doi:10.1109/THMS.2015.2504081

Kring, A. M., & Sloan, D. M. (2007). The Facial Expression Coding System (FACES): Development, Validation, and Utility. Psychological Assessment, 19(2), 210-224. doi:10.1037/1040-3590.19.2.210

Larson, C., Aronoff, J., & Steuer, E. (2011). Simple geometric shapes are implicitly associated with affective value. Motivation and Emotion, 36(3), 404–413. doi:10.1007/s11031-011-9249-2

Lewis, C., & Lovatt, P. (2013). Breaking away from set patterns of thinking: Improvisation and divergent thinking. Thinking Skills and Creativity, 9(9), 46-58. doi:10.1016/j.tsc.2013.03.001

Lin, W., Li, C., & Zhang, Y. (2022). Emotion visualization system based on physiological signals combined with the picture and scene. Information Visualization, 21(4), 393–404. doi:10.1177/14738716221109146

Liu, Y., Sourina, O., & Nguyen, M. K. (2010). Real-Time EEG-Based Human Emotion Recognition and Visualization. 2010 International Conference on Cyberworlds, 262-269. doi:10.1109/CW.2010.37

Lu, X., Suryanarayan,, P., Adams, R. B., Li, J., Newman, M. G., & Wang, J. Z. (2012). On Shape and the Computability of Emotions. Proceedings of the 20th ACM International Conference on Multimedia. doi:10.1145/2393347.2393384

Machajdik, J., & Hanbury, A. (2010). Affective Image Classification using Features Inspired by Psychology and Art Theory. Proceedings of the International Conference on Multimedia - MM ’10, 83-92. doi:10.1145/1873951.1873965

Malaga, R. A. (2000). The effect of stimulus modes and associative distance in individual creativity support systems. Decision Support Systems, 29(2), 125-141. doi:10.1016/S0167-9236(00)00067-1

Mann, S. B. (2020, December 26). 100 Brain Teasers With Answers for Kids and Adults. IcebreakerIdeas. https://icebreakerideas.com/brain-teasers/

Manovich, L. (2002). The Anti-Sublime Ideal in Data Art. Berlin. Retrieved November 2, 2022, from http://www.manovich.net/DOCS/data_art.doc

Mauss, I. B., & Robinson, M. D. (2009). Measures of emotion: A review. Cognition & emotion, 23(2), 209–237. doi:10.1080/02699930802204677

McCormack, J., & Dorin, A. (2001). Art, Emergence, and the Computational Sublime. International Conference on Generative Systems in the Electronic Arts 2001, 67-81. Retrieved from https://philpapers.org/rec/MCCAEA-4

Milgram, R. M., & Milgram, N. A. (1976). Creative thinking and creative performance in Israeli students. Journal of Educational Psychology, 68(3), 255-259. doi:10.1037/0022-0663.68.3.255

Nemiro, J. E. (2016). Connection in Creative Virtual Teams. Journal of Behavioral and Applied Management,, 2(2), 814.

Nummenmaa, L., Glerean, E., Viinikainen, M., Jääskeläinen, I. P., Hari, R., & Sams, M. (2012). Emotions promote social interaction by synchronizing brain activity across individuals. Proceedings of the National Academy of Sciences, 109(24), 9599–9604. doi:10.1073/pnas.1206095109

Oppezzo, M., & Schwartz, D. L. (2014). Give Your Ideas Some Legs: The Positive Effect of Walking. Journal of Experimental Psychology: Learning, Memory, and Cognition, 40(4), 1142–1152. doi:10.1037/a0036577

Palanica, A., & Fossat, Y. (2022). Effects of nature virtual backgrounds on creativity during videoconferencing. Thinking Skills and Creativity, 43, 100976. doi:10.1016/j.tsc.2021.100976

Panksepp, J. (1998). Affective Neuroscience: The Foundations of Human and Animal Emotions. New York: Oxford University Press.

Patnaik, S. (2020, April 2). Zoom pulls in more than 200 million daily video users during worldwide lockdowns. Retrieved November 2, 2022, from Reuters: https://www.reuters.com/article/us-health-coronavirus-zoom-idUSKBN21K1C7

Petchkovsky, L. (2008). Some preliminary Reflections on the Biological Substrate of meaning-making the Uses of subjective experience. In The Uses of subjective experience. Proceedings of the Conference ‘The Uses

of Subjective Experience: A Weekend of Conversations between ANZSJA Analysts and Academics who Work with Jung's Ideas, (pp. 20-21).
Phon-Amnuaisuk, S., & Panjapornpon, J. (2012). Controlling Generative Processes of Generative Art. Procedia Computer Science, 13, 43-52. doi:10.1016/j.procs.2012.09.112
Pinna, B. (2012). What is the Meaning of Shape? Gestalt Theory, 33(3/4), 383-422.
Reas, C., & Fry, B. (2006). Processing: programming for the media arts. AI & SOCIETY, 20(4), 526–538. doi:10.1007/s00146-006-0050-9
Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing Fluency and Aesthetic Pleasure: Is Beauty in the Perceiver's Processing Experience? Pcrsonality and Social Psychology Review, 8(4). doi:10.1207/s15327957pspr0804_3
Russell, J. A. (1980). A circumplex model of affect. Journal of Personality and Social Psychology, 39(6), 1161–1178. doi:10.1037/h0077714
Russell, J. A. (1994). Is there universal recognition of emotion from facial expression? A review of the cross-cultural studies. Psychological Bulletin, 115(1), 102-141. doi:10.1037/0033-2909.115.1.102
Sandhu, R. K., Vasconcelos-Gomes, J., Thomas, M. A., & Oliveira, T. (2023). Unfolding the popularity of video conferencing apps – A privacy calculus perspective. International Journal of Information Management, 68, 102569. doi:10.1016/j.ijinfomgt.2022.102569
Schwarz, N. (2002). Situated cognition and the wisdom of feelings: Cognitive tuning. In The wisdom in feeling (pp. 144-166). New York: Guilford Press.
Schwarz, N., & Bless, H. (1991). Happy and mindless, but sad and smart? The impact of affective states on analytic reasoning, Garland Science. In Emotion and Social Judgements (pp. 55-71). Garland Science.
Unemi, T. (2002). SBART 2.4: an IEC Tool for Creating 2D Images, Movies, and Collage. Leonardo, 35(2), 189-191.
Viégas, F. B., & Wattenberg, M. (2007). Artistic Data Visualization: Beyond Visual Analytics. Online Communities and Social Computing, 182–191. doi:10.1007/978-3-540-73257-0_21
Ward, T. B., Patterson, M. J., & Sifonis, C. (2004). The role of specificity and abstraction in creative idea generation. Creativity Research Journal, 16(1), 1-9. doi:10.1207/s15326934crj1601_1
Watson, D. (2000). Mood and Temperament (1 ed.). New York: The Guilford Press.
Xu, L., Mehta, R., & Hoegg, J. (2022). Sweet ideas: How the sensory experience of sweetness impacts creativity. Organizational Behavior and Human Decision Processes, 172, 104169. doi:10.1016/j.obhdp.2022.104169

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