E-Motioning: Exploring the Effects of Emotional Generative Visuals on Creativity and Connectedness during Videoconferencing

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ABSTRACT

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, a system that generates geometrical-based visuals according to users' real-time emotions, as backgrounds for videoconferencing. The experiment was conducted with twenty-four participants to examine the effects of E-Motioning on creativity and connectedness in Microsoft Teams under two conditions: (1) control (real physical environment as background) and (2) E-Motioning. 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, Computer Art, Facial Expression Recognition, Emotion Visualization, Videoconferencing, Creativity, Social Connectedness

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 communication (Brown et al., 2010; Short et al., 1976) alongside 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 videoconferencing interactions 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 if such feedback is missing, then additional dimensions may be necessary to create connected, coordinated, and collaborative working environments and thus enhance creativity.

This study seeks to investigate how the aforementioned factors could be improved from the perspective of missing social cues. Therefore, E-Motioning has been proposed, a system that can generate geometrical-based visuals according to users' real-time emotions, 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?

The rest of the paper is structured as follows. In Chapter 2, the existing studies on the topic are reviewed and hypotheses are formulated. The design process is outlined in Chapter 3, while Chapter 4 describes the experimental methods employed. This is followed by Chapter 5, which presents the results. Chapter 6 offers a thorough discussion of the limitations of the study and presents recommendations for future work. Lastly, Chapter 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). 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 can 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. This is described in the "Circumflex of Affect" (Russell, 1980).

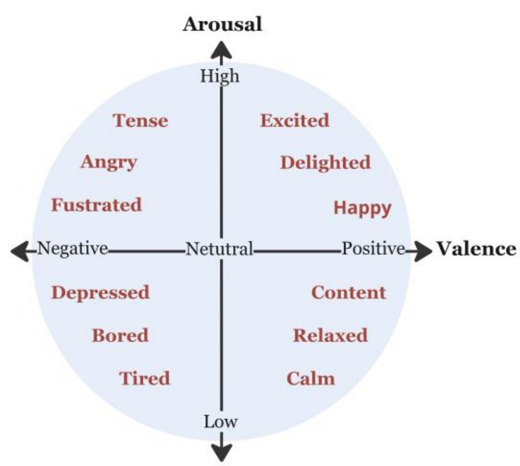

Figure 1: Two-dimensional valence-arousal emotion, adapted from Russell (1980).

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 significant features were identified through a combination of theoretical 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, mapping emotions to 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 as followed, which has been used to select the generated images to present to the respondents.

Emotion	Shape	Color
Positive	Circle	Orange Yellow
Neutral	Square	Green Blue
Negative	Triangle/Line	Grey Black

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

3.1.3 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. The details of them can be found in Appendix I. Respondents were asked to select three images that best represented positive, neutral, or negative emotions, respectively. Besides that, they also completed a survey (Appendix II) 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.

3.1.4 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 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 and China (Figure 2). Respondents had similar characteristics to the final experimental participants' sample, but they were not part of the sample pool.

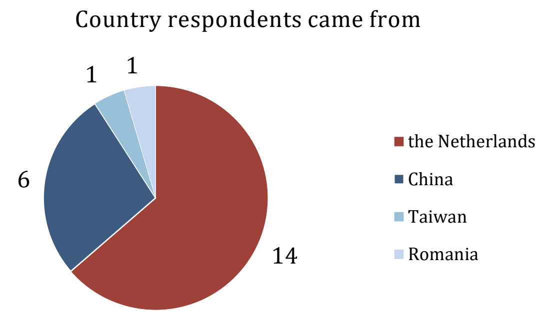

Figure 2: Respondents by country.

3.1.5 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 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. Detailed statistics can be found in Appendix III.

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

Table 2: Significant features of emotions.

These emotion-related features, combing with some other features, have been controlled by different parameters or combinations of parameters in the generative visual system, which has been further described in 3.2.2.

3.2 E-Motioning

The E-Motioning system consists of three main parts, as illustrated in Figure 3. This section describes each of them in detail.

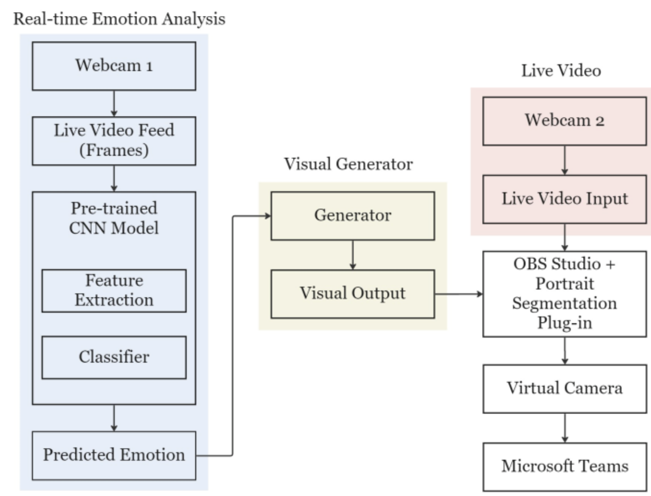

Figure 3: The architecture of the E-Motioning system.

The complete code for the E-Motioning system is available on GitHub and can be accessed through the link: https://github.com/TQmsu/E-Motioning.git.

3.2.1 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 to recognize 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%. For details of the model's performance, see Appendix IV.

3.2.2 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.

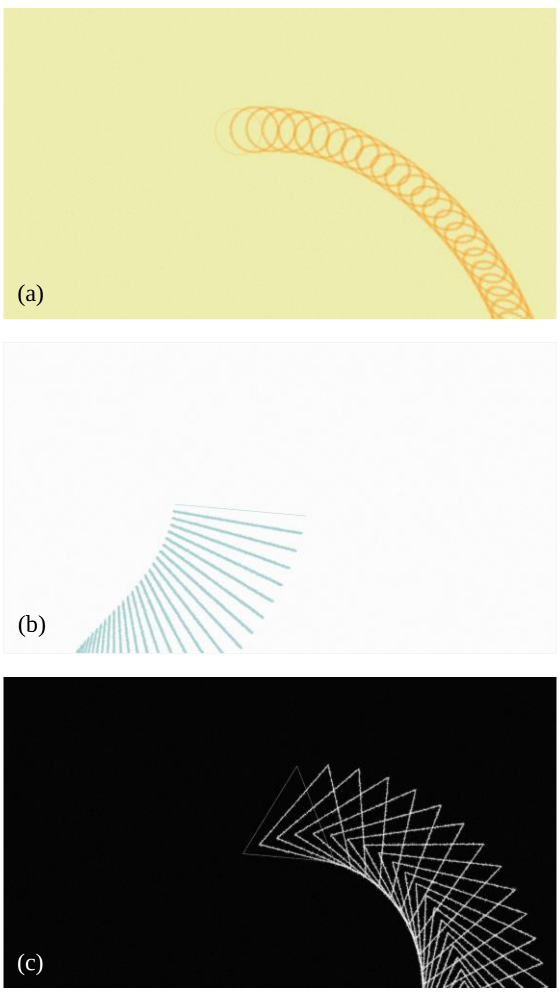

Figure 4: Examples of visuals generated by E-Motioning representing three emotional types: (a) positive; (b) neutral; (c) negative.

3.2.3 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 5. This was done by right-clicking the video and selecting the “pin” option.

Figure 5: 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 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:

		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

Table 3: Demographic information of the participants.

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 real 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 mostly 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 (Appendix V) were prepared; the order in which they were asked was randomized. The actual number of questions asked varied according to the speed of the participant's response. To potentially elicit negative emotions, the assistant also provided verbal countdown reminders of thirty seconds and fifteen seconds remaining.

4.3 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 (Appendix VI). 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).

A post-questionnaire (Appendix VII) was administered to the experimental group for gathering qualitative data at the end of the experiment. It 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 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.

4.4.1 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 referred 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). A detailed example of the AUT assessment process in this study can be found in Appendix VIII.

All components were rigorously assessed by a primary coder (the researcher). To provide an additional check on the accuracy and to minimize biases of the scores, a secondary coder, the experimental assistant, scored a randomly selected subset of 20% of the responses, independently. The high level of agreement (r = 0.90) between the primary and secondary coders attested to the accuracy of the scores.

4.4.2 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 6) 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 evaluated as a reliable and valid measure of subjective closeness in relationships, with demonstrated applicability to various samples (Gächter et al., 2015).

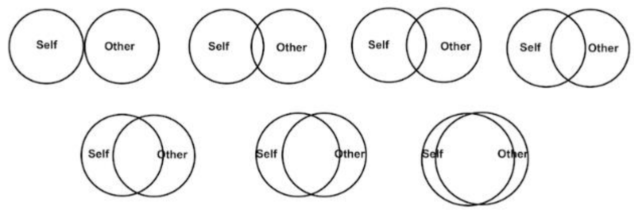

Figure 6: The IOS scale, where 1=no overlap; 2=little overlap; 3=some overlap; 4=equal overlap; 5=strong overlap; 6=very strong overlap; 7=most overlap (Gächter et al., 2015).

4.5 Data Analysis

The quantitative data collected from the questionnaires were imported to Microsoft Excel and analyzed by 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 7.

However, 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, leading to its rejection.

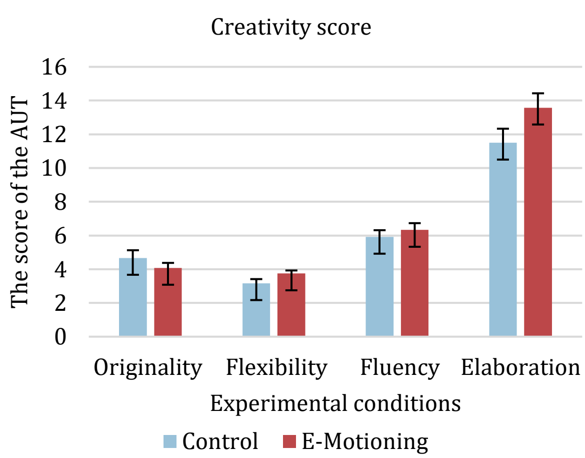

Figure 7: Scores for the four components of creativity in the two study conditions (displayed with standard error bars).

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 (η^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.

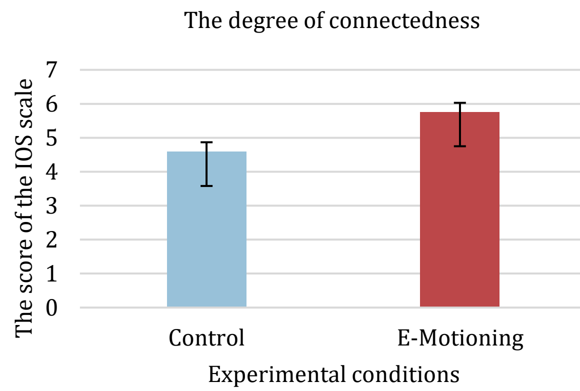

Figure 8: The mean differences and standard errors of the level of connectedness, measured by the IOS scale (displayed with standard error bars).

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, which could be due to the limitations 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.

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.

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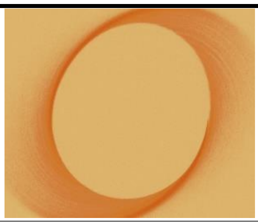
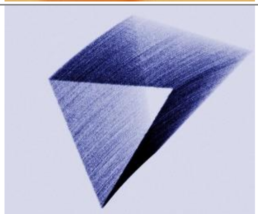
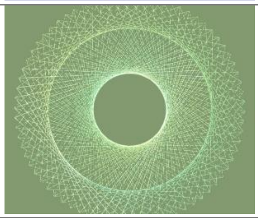
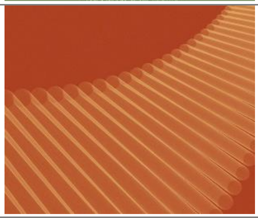
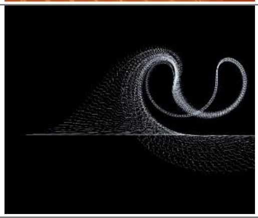
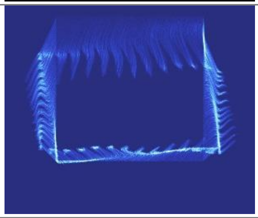
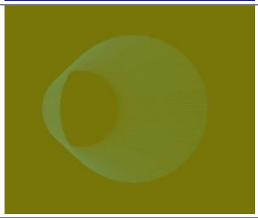
Appendix I EXAMPLE GENERATED IMAGES

Item	Example image	Emotion	Shape	Color
I1		Positive	Circle	Orange
I2		Negative	Triangle	Blue
I3		Neutral	Circle	Green
I4		Positive	Circle	Red - Orange
I5		Negative	Line	Black
I6		Neutral	Square	Blue
I7		Positive	Circle	Green

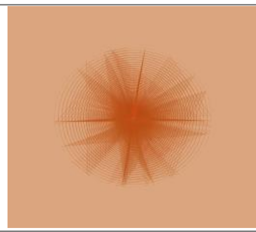
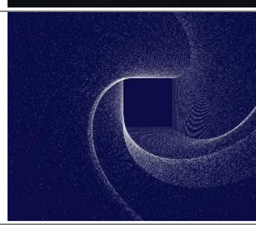
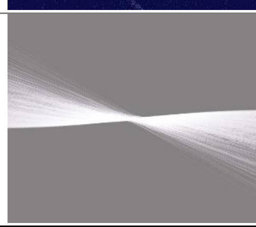
I8		Positive	Circle	Orange
I9		Positive	Circle	Yellow - green
I10		Negative	Triangle	Black
I11		Neutral	Square	Blue
I12		Neutral	Line	Grey

Table I1: Overview of the example visuals for the user study.

Appendix II DESIGN RULES EXPLORATATION

E-Motioning - A system that generates visuals through emotions

Hey, I am Tianqin Lu. Welcome to my project about investigating the impact of emotional generative visuals in videoconferencing.

In this project, In this project, I am designing E-Motioning, an intelligent system that detects user emotions and generates corresponding visuals. Color and shape are important parameters in the system in relation to emotion, for which I am currently testing how well users understand the rules I have designed and gathering any other valuable insights.

The information collected will be anonymous and only seen by myself.

This survey will take approximately 4 minutes to complete. Your participation is very much appreciated, thank you!

1. Which colour represents 'positive emotion' to you (choose only one) ?
   ○ Black ○ White ○ Yellow ○ Orange ○ Blue ○ Green ○ Other ____
2. Please explain why.
3. Which colour represents 'negative emotion' to you (choose only one) ?
   ○ Black ○ White ○ Yellow ○ Orange ○ Blue ○ Green ○ Other ____
4. Please explain why.
5. Which colour represents 'neutral emotion' to you (choose only one) ?
   ○ Black ○ White ○ Yellow ○ Orange ○ Blue ○ Green ○ Other ____
6. Please explain why.
7. Which shape represents "positive emotion" to you (choose only one) ?
   ○ Square ○ Line ○ Circle ○ Triangle ○ Other ____
8. Please explain why.
9. Which colour represents 'negative emotion' to you (choose only one) ?
   ○ Square ○ Line ○ Circle ○ Triangle ○ Other ____
10. Please explain why.
11. Which colour represents 'neutral emotion' to you (choose only one) ?
    ○ Square ○ Line ○ Circle ○ Triangle ○ Other ____
12. Please explain why.
13. Are there any other parameters in visual/art that you feel can strongly express your emotions (positive, neutral, negative)? If so, please share it with me!

Demographic information of the participant

14. Gender:
    ○ Male ○ Female ○ Non-binary ○ Prefer not to say
15. Age: ____
16. What country are you from? ____

Appendix III RESULTS OF THE USER EVALUATION

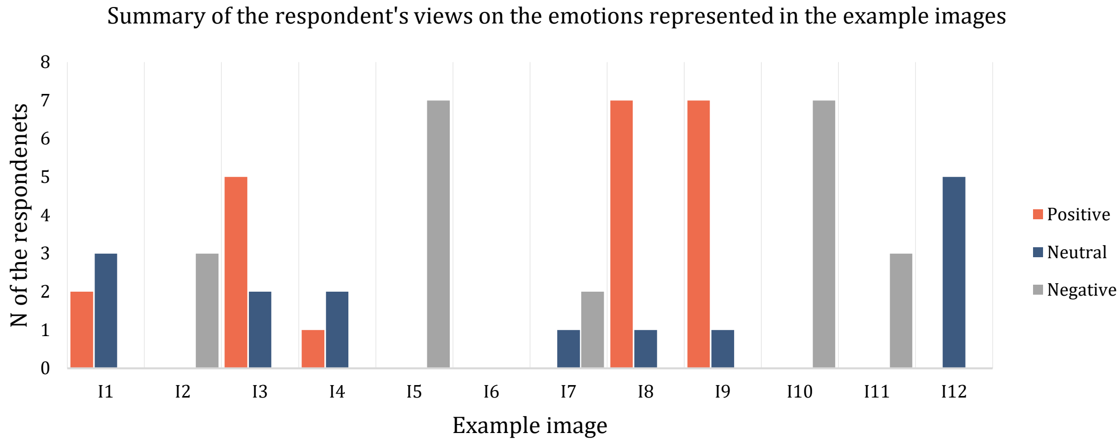


Figure III1: Respondents' views on the emotions represented in the example images (X-axis is the number of example images; Y-axis is the number of respondents).

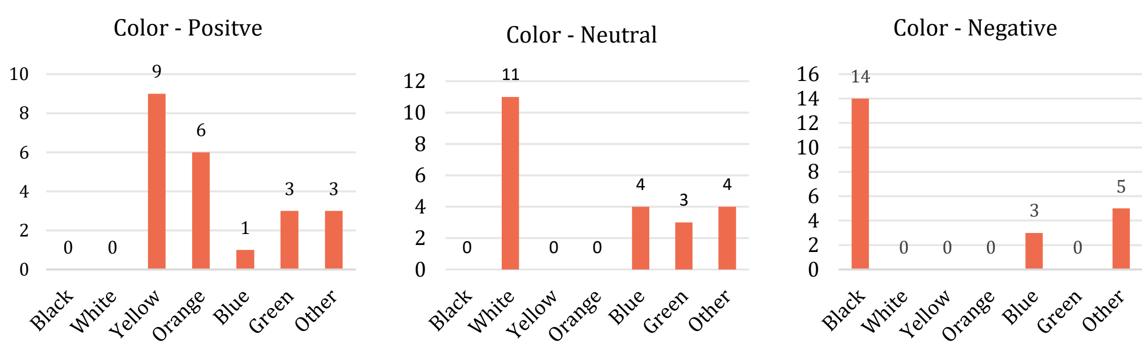


Figure III2: Results of respondents' preference for emotion-color relationship (X-axis is the number of respondents; Y-axis is the type of color).

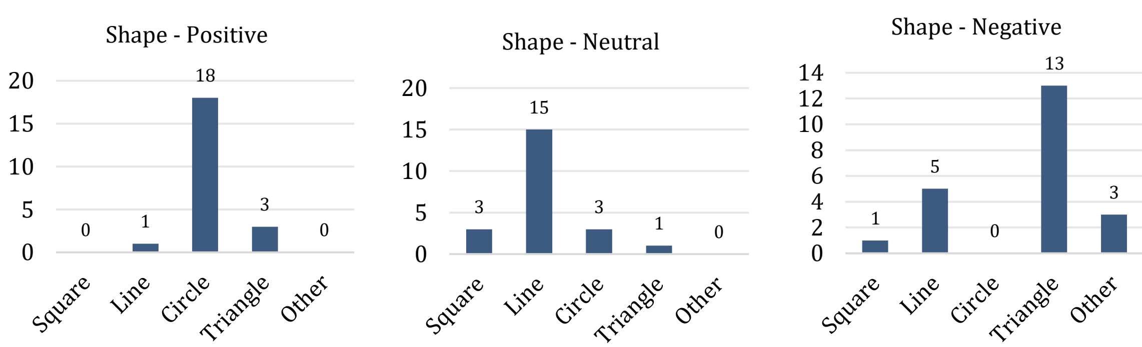


Figure III3: Results of respondents' preference for emotion-shape relationship (X-axis is the number of respondents; Y-axis is the type of shape).

Appendix IV FACIAL EMOTION RECOGNITION MODEL PERFORMANCE

```
Epoch 197/200
798/798 [==============================] - 161s 202ms/step - loss: 0.5054 - accuracy: 0.7916 - val_loss: 0.4928 - val_accurac
y: 0.8038
Epoch 198/200
798/798 [==============================] - 161s 201ms/step - loss: 0.5007 - accuracy: 0.7944 - val_loss: 0.5113 - val_accurac
y: 0.8005
Epoch 199/200
798/798 [==============================] - 161s 201ms/step - loss: 0.5119 - accuracy: 0.7897 - val_loss: 0.4883 - val_accurac
y: 0.8068
Epoch 200/200
798/798 [==============================] - 161s 202ms/step - loss: 0.5078 - accuracy: 0.7910 - val_loss: 0.4962 - val_accurac
y: 0.8030
```

Figure IV1: Model accuracy with the increasing number of epochs.

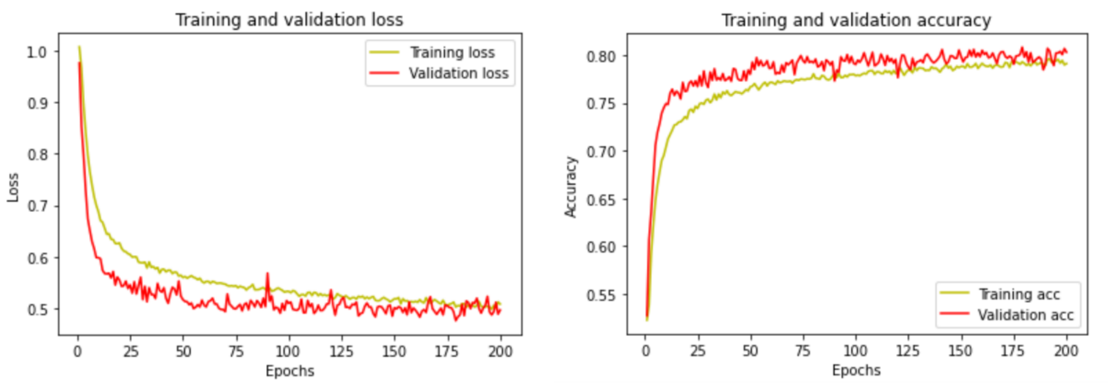


Figure IV2: Model performance with the increasing number of epochs.

Appendix V BRAIN TEASER QUESTIONS

The following brain teasers (Mann, 2020) were employed in the experiment to ask questions of the participants

1. You are a cyclist in a cross-country race. Just before the crossing finish line, you overtake the person in second place. In what place did you finish?
   Answer: Second Place. If you pass the person in second, you take second place, and they become third.
2. A man is looking at a photograph of someone. His friend asks who it is. The man replies, "Brothers and sisters, I have none. But that man's father is my father's son." Who was in the photograph?
   Answer: His son.
3. Your parents have six sons including you and each son has one sister. How many people are in the family?
   Answer: Nine. Two parents, six sons, and one daughter. All of them have one sister (not six sisters).
4. As I was going to Rotterdam, I met a man with seven wives. Each wife had seven sacks, Each sack had seven cats, Each cat had seven kits. How many were going to Rotterdam?
   Answer: One. Only I was going to Rotterdam.
5. I do not have any special powers, but I can predict the score of any football game before it begins. How can I do this?
   Answer: Well, the score before any football game is always zero to zero!
6. Imagine that you are in a boat, in the middle of the sea. Suddenly, you are surrounded by hungry sharks, just waiting to feed on you. How can you put an end to this?
   Answer: Stop imagining!
7. Jimmy's mother had four children. She named the first Monday. She named the second Tuesday, and she named the third Wednesday. What is the name of the fourth child?
   Answer: Jimmy, because Jimmy's mother had four children!
8. A plane crashes on the border of the U.S. and Canada. Where do they bury the survivors?
   Answer: You do not bury the SURVIVORS!
9. Who is bigger: Mr. Bigger, Mrs. Bigger, or their baby?
   Answer: The baby, because he is a little bigger.
10. In a year, there are 12 months. Seven months have 31 days. How many months have 28 days?
    Answer: They all do.
11. Four cars come to a four-way stop, all coming from a different direction. They can't decide who got there first, so they all go forward at the same time. They do not crash into each other, but all four cars go. How is this possible?
    Answer: They all made right-hand turns
12. During which month do people sleep the least?
    Answer: February (there are usually fewer nights in February).

Appendix VI CONSENT FORM

E-Motioning: Exploring the Effects of Emotional Generative Visuals on Creativity and Connectedness during Videoconferencing

Dear Sir/Madam,

You are asked to take part in a scientific study.

Participation is voluntary. Participation requires your written consent. Before you decide whether you want to participate in this study, you will be given an explanation about what the study involves. Please read this information carefully and ask the investigator for an explanation if you have any questions. You may also discuss it with your partner, friends or family.

Purpose of the study
E-Motioning is a generative visual system, which detects the user's real-time emotions and translates them to geometrical-based visuals to be used as background for videoconferencing. E-Motioning conveys those detected emotions in an artistic way and allows users to exchange their real-time emotive information in the background thus aiming to enhance their social connectivity. At the same time, the abstract and random artistic presentation is expected to stimulate the creativity of remote workers.

What participation involves
During the study, the following will happen:

You will be randomly assigned to one of the two different conditions: Control and E-Motioning. You will be working with an experimental assistant to complete during the experiment. The whole experiment will take approximately **25** minutes.

Appendix A describes what procedures will take place during each visit.

What is expected of you
In order to carry out the study properly, it is important that you follow the study instructions.

It is important that you contact the investigator:
- if you no longer want to participate in the study.
- if your contact details change.

If you do not want to participate or you want to stop participating in the study
It is up to you to decide whether or not to participate in the study. Participation is voluntary. If you do participate in the study, you can always change your mind and decide to stop, at any time during the study. You do not have to say why you are stopping, but you do need to tell the investigator immediately. The data collected until that time will still be used for the study. If there is any new information about the study that is important for you, the investigator will let you know. You will then be asked whether you still want to continue your participation.

End of the study
Your participation in the study stops when
- you choose to stop
- the end of the entire study has been reached
- the investigator considers it best for you to
- The government or Ethical Review Board, decides to stop the study.

The study is concluded once all the participants have completed the study.

Usage and storage of your data
Your personal data will be collected, used and stored for this study. The collection, use and storage of your data is required to answer the questions asked in this study and to publish the results. We ask your permission for the use of your data.

Confidentiality of your data
To protect your privacy, your data will be given a code. Your name and other information that can directly identify you, will be omitted. Data can only be traced back to you with the encryption key. The encryption key remains safely stored in the local research institute. The data that is sent to the supervisors will only contain the code, not your name or other data with which you can be identified. The data cannot be traced back to you in reports and publications about the study.

Access to your data for verification
Some people can access all your data at the research location. Including the data without a code. This is necessary to check whether the study is being conducted in a good and reliable manner. Persons who have access to your data for review: the committee that monitors the safety of the study, national and international supervisory authorities. They will keep your data confidential. We ask you to consent to this access.

Retention period of your data
Your data must be kept for one year at the research location.

Storage and use of data other research
Your data may also be of importance for other scientific research in the field of the further development of the product. To this end, your data will be stored for one year. You can indicate on the consent form whether or not you agree with this. If you do not agree with this, you can still participate in the current study.

Withdrawing consent
You can withdraw your consent to the use of your personal data at any time. This applies to this study and also to storage and use for future research. The study data collected until the moment you withdraw your consent will still be used in the study.

More information about your rights when processing data
For general information about your rights when processing your personal data, you can consult the website of the Dutch Data Protection Authority.

If you have questions about your rights, please contact the person responsible for the processing of your personal data. For this study, that is: Tianqin Lu (t.lu@student.tue.nl).

If you have questions or complaints about the processing of your personal data, we advise you to first contact the research location. You can also contact the Data Protection Officer of the institution or the Dutch Data Protection Authority.

Any questions?
If you have any questions, please contact Tianqin Lu (t.lu@student.tue.nl).

If you have any complaints about the study, you can discuss this with the investigator. If you prefer not to do this, you may contact the Ethics Committee at the TU/e by ethics@tue.nl

Signing the consent form
When you have had sufficient time for reflection, you will be asked to decide on participation in this study. If you give permission, we will ask you to confirm this in writing on the appended consent form. By your written permission you indicate that you have understood the information and consent to participation in the study. The signature sheet is kept by the investigator. Both the Investigator and yourself receive a signed version of this consent form.

Thank you for your attention.

Appendix A: Experimental Procedures

You will perform this experiment together with the experimental assistant (EA) via MS Teams. The whole experiment will take approximately **25** minutes.

Before test

Please read the consent forms and fill in some basic information.

Test

During the 15-minute online meeting, you will first answer some brain teaser questions,
Then you will take a 2-minute Alternative Uses Test to list as many alternative uses for a shoe as possible.

After test

Please fill in the post-questionnaire and take the post-interview .

Appendix B: Subject Consent Form

E-Motioning: Exploring the Effects of Emotional Generative Visuals on Creativity and Connectedness during Videoconferencing

- I have read the subject information form. I was also able to ask questions. My questions have been answered to my satisfaction. I had enough time to decide whether to participate.
- I know that participation is voluntary. I know that I may decide at any time not to participate after all or to withdraw from the study. I do not need to give a reason for this.
- I give permission for the collection and use of my data to answer the research question in this study.
- I know that some people may have access to all my data to verify the study. These people are listed in this information sheet. I consent to the inspection by them.

- I □ **do**

  □ **do not**
  consent to keeping my personal data longer and to use it for future research in the development of the product.
- I □ **do**

  □ **do not**
  consent to being contacted again after this study for a follow-up study.
- I want to participate in this study.

Name of study subject:

Signature: Date: __ / __ / __

I hereby declare that I have fully informed this study subject about this study.

If information comes to light during the course of the study that could affect the study subject's consent, I will inform him/her of this in a timely fashion.

Appendix VII POST-QUESTIONNAIRE

- To what extent do you understand the visuals expressed by the system? And why?
- Is there anything else you'd like to see shown in the generative visuals? For example, stress. If so, please give a description.
- Would you use or utilize the system in the future? and why?
- What grade do you give the system as a whole, on a scale of 1–10?
- Do you have any suggestions for improving the system?
- Is there anything else you would like to share? (Optional)

Appendix VIII AUT ASSESSMENT PROCESS

Alternative usage ideas for a shoe	Code	Originality	Flexibility	Fluency	Elaboration
Container	Container	0	Code 1	Idea 1	1
Bowl	Container	1	Code 1	Idea 2	1
Kick it like a ball	Sport	0	Code 2	Idea 3	4
Flower pot	Container	1	Code 1	Idea 4	2
Weapon	Weapon	1	Code 3	Idea 5	1
Gift to friends	Gift	1	Code 4	Idea 6	3
Home for cat or bird	Accommodation	1	Code 5	Idea 7	5
	Net score for Participant 1	**5**	**5**	**7**	**17**

Table VIII1: Example of AUT assessment process for Participant 1.

Appendix IX DESCRIPTIVE STATISTICS & ANOVA ANALYSIS

Variable name	Condition	Sample size	Mean	Standard deviation	Standard error	F	p
The level of connectedness	Control	12	4.75	0.87	0.29	7.135	0.014**
	E-Motioning	12	5.75	0.97	0.32		

Note: ***, **, * represent the significance levels of 1%, 5%, and 10% respectively.

Table IX1: Descriptive statistics and ANOVA result of the IOS scale.

Analysis item	Difference between groups	Total deviation	Partial Eta square (Partial η^2)	Cohen's f-value
The level of connectedness	6	24.5	0.245	0.569

Table IX2: Effect quantification analysis of the IOS scale.

Variable name	Condition	Sample size	Mean	Standard deviation	Standard error	F	P
Originality	Control	12	4.67	2.23	0.46	0.579	0.455
	E-Motioning	12	4.08	1.44	0.29		
Flexibility	Control	12	3.17	1.19	0.24	1.878	0.184
	E-Motioning	12	3.75	0.87	0.18		
Fluency	Control	12	5.92	1.93	0.39	0.274	0.606
	E-Motioning	12	6.33	1.97	0.40		
Elaboration	Control	12	11.50	4.08	0.83	1.532	0.229
	E-Motioning	12	13.58	4.17	0.85		

Table IX3: Descriptive statistics and ANOVA result of the creativity analysis.

Appendix X EXPERIMENTAL DATA

N. of Participant	Experimental condition	Familiarity with brain teaser questions (on a scale of 1 to 5)	The IOS score	System score
1	Control	2	4	-
2	E-Motioning	2	5	7
3	E-Motioning	3	5	8
4	Control	4	5	-
5	Control	1	6	-
6	E-Motioning	2	6	6
7	Control	3	4	-
8	Control	1	4	-
9	E-Motioning	1	7	9
10	E-Motioning	2	7	6
11	Control	3	5	-
12	Control	2	4	-
13	E-Motioning	3	4	7
14	Control	2	5	-
15	E-Motioning	3	6	8
16	Control	1	4	-
17	Control	1	6	-
18	Control	2	4	-
19	E-Motioning	1	5	8
20	E-Motioning	2	6	-
21	Control	1	6	8
22	E-Motioning	1	6	9
23	E-Motioning	2	5	10
24	E-Motioning	3	7	7

Table X1: Summary of experimental raw data (excluding creativity analysis data).

N. of Participant	Responses of alternative usage ideas for a shoe
1	Container, bowl, kick it like a ball, flower pot, weapon, gift to friends, home for cat or bird
2	T-shirt, plastic bags, handbag, scarf, tape, bottle, rope, stickers, coat
3	Your feet, your sock, sleeves of your sweater, wheel on your feet, bag, plastic bag that you can place
4	Sock, hat, a pen, snowboard, plastic bag, ski’s
5	Wooden block, wooden plank, container of a beverage
6	Football, cross body bag, bottle, snake box, weapon, small boat, animal home
7	Snowboard, skiboots, food, sock, floor, clothing
8	Your dinking bottle, coffee cup, organizer, vase, handbag, swords, a weapon you can use to defence yourself
9	Plastic bag, makeup bag, a pan, snowboard, a sock, a toy for the cat, home for small birds
10	A place to hide money, snack box, cup, mug, heavy bag, tiny boat, weapon, recyclable materials
11	Hat, earring, bag, lamp, a board that you can write

12	Bag, a box you can put your things in, furniture, vase
13	Sock, prosthetic, a ball that can be kicked, volleyball, basketball, ping pong, A ball to play with the dog
14	Snowboard, skate, glove, a bowl for eating food, cup, bottle, a place to raise flowers, birdhouse
15	Hairpin, hat, tissue, a thing you can use to get some water and drink it
16	Weapon, frisbee, planter, plate, bowl, spoon
17	Wipe, a tool you can use to sweep the floor, box, small bag, umbrella holder
18	A place you put your hand in, glove, hat, bare sock
19	Boat (not for human), weapon, mobile phone
20	Plastic bag, shopping bag, scarf, aromatherapy, trash bin
21	Mouse, laptop stand, tie, a hanging decoration, hat, shelf, clip, table, chair, couch
22	Sock, brace when break your leg, brooch, hook, shelf for hanging the toilet paper, pillow, doorstop
23	Clothing, gift, umbrella, clothes hangers, hook, cabinet, fridge sticker, lunchbox, hand bag
24	Accessory, neck protection brace, hat, a thing to keep you warm

Table X2: Participants' responses to the AUT test.

N. of Participant	Creativity analysis			
	Originality	Flexibility	Fluency	Elaboration
1	5	5	7	17
2	6	5	9	10
3	3	3	6	19
4	5	3	6	8
5	3	2	3	8
6	4	5	7	12
7	6	4	6	6
8	4	3	7	17
9	5	4	7	18
10	5	4	8	16
11	4	4	5	10
12	2	2	4	11
13	3	3	7	19
14	6	4	8	16
15	3	4	4	15
16	6	4	6	6
17	2	2	5	15
18	3	1	4	11
19	2	3	3	7
20	3	3	5	8
21	10	4	10	13
22	6	3	7	16
23	6	5	9	12
24	3	3	4	11

Table X3: Overview of the scores of the participants' responses on the four dimensions of creativity analysis.