Neo-Noumena

Figure 1: A representation of what participants see while using Neo-Noumena. During this experience, two participants can see each other's fractal swarms which are generated in accordance with their concurrent affective state, while the wearable nature of the system permits the participants to move around.

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Abstract
Communicating emotional experiences is something core to being human, yet also notoriously difficult. With this considered, we acknowledge previous work in bio-responsive and neurofeedback systems which facilitate the externalization of subjective experiences, which highlight potential for the appropriation of Neurofeedback for communication. We present a demonstration that explores this opportunity through "Neo-Noumena", a communicative neuro-responsive system that augments the interpersonal communication of emotion through brain-computer interfacing and artificial intelligence, which interprets the users affective state and dynamically to others in mixed reality through two head-mounted displays. The user will, with a partner, experience their affective state translated into an aural swarm of procedurally generated, emotionally informative fractals.

Introduction
Subjective experiences of emotion are difficult to communicate about. Our limited communicative faculties force us to squeeze our complex experiences through "information bottlenecks", producing language and gestures [13]. We argue that technology has the potential to enhance emotion communication, though most efforts have only supplemented areas where communication is already restricted, such as using emojis during texting. We propose to take advantage of new technologies such as mobile electroencephalography (EEG) devices and mixed

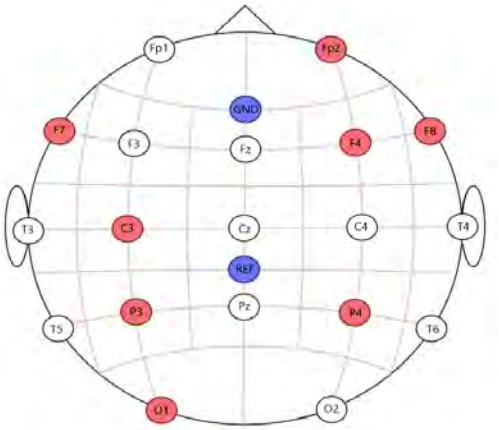

Figure 2: This figure represents the EEG electrode placement employed by Neo-Noumena, with recoding sights being Fp2, F4, F7, F8, C4, P3, P4, O1, AFz (ground), and CPz (reference).

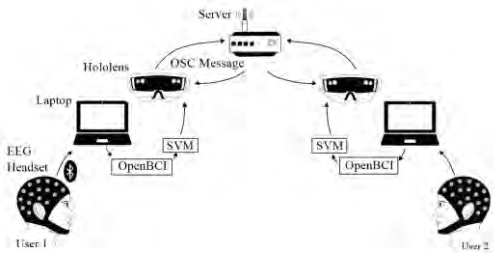

Figure 3: This figure illustrates the system architecture of Neo-Noumena.

reality (MR) with our system, "Neo-Noumena", to augment everyday emotion communication.

Neo-Noumena is a system that uses EEG to drive procedural content generation viewable using head mounted displays (HMDs). The aim is to provide additional dimensions of emotion to interpersonal communication through dynamic, artistic representations. EEG data is classified along dimensions of emotion though a support vector machine, which produce different fractal images using procedural content generation. We argue that these fractals augment users' communication of their emotions, and aid interpretation of others' emotions.

Related Work

Emotion Communication Systems

Liu et al. [8] designed a system which used EEG data to attempt to extract individual's experiences of emotion from neural activity. This information was used to animate the facial expressions of a virtual avatar to match the emotional state of the participant, demonstrating the efficacy of using BCI technology to form accurate representations of emotion. However, the system only emulates human facial expressions, and therefore does not extend emotion communication beyond our current capability.

Neurofeedback for Procedural Content Generation

Several other systems have demonstrated efficacy in representing subjective states using interactive technologies, often through neurofeedback or neuro-reactive properties. Examples include: "Inner Garden" [9], which populates a projected tabletop world to facilitate meditativeness; "Inter-Dream" [11], which projects neural data as procedurally generated abstract imagery; and "Lucid loop" [6], which trains people to lucid dream, by enabling users' lucidity to modify art generation by a DCNN.

Interpersonal Mixed Reality

Past research has also shown MR to be a viable communication medium. For instance: "BrainShare"[5], is an AR-BCI system designed to enable communication for patients with locked-in syndrome by transmitting instructions to a caretaker's POV; and "FingAR", which superimposes imaginary objects on physical play props using AR, which was shown to promote emotional expression and awareness in child participants [1].

Neo-Noumena

Neo-Noumena interprets EEG data to classify participants' subjective emotional experiences. To achieve this, eight channels of EEG data are collected via an electrode cap connected to an OpenBCI Cyton amplifier relayed over OSC to a HoloLens through a UDP server. The raw EEG signal is sampled at a rate of 250Hz, passed through a 50Hz notch filter and a 5-50Hz bandpass filter, and finally processed through a mean smoothing filter to mitigate movement artifacts. Features from filtered data are then extracted and interpreted by a support vector machine classifier to categorize the participant's emotional state. The classifier was trained using the DEAP dataset [7], assessing emotion based on dimensions of arousal and valence.

Procedural Content Generation to Represent Emotion

Each classification generates a fractal image which differ by shape node count, line smoothness, relative angle sizes, rate of change, color, and four different movement patterns, which together create unique

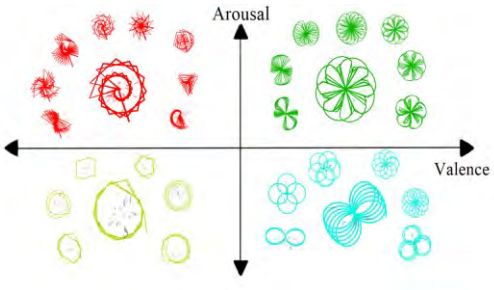

Figure 4: This figure illustrates the four categories Neo-Noumena assigns affective data to, along with samples of the corresponding fractals these classifications generate.

evolving patterns. From the experiential perspective of the participant, Neo-Noumena renders emotional states into AR as swarms of eight fractals, akin to an "aura" that surround the participant. This swarm is generated in the participants' proximity at a range of ca. 1.2m. As participants move around, their swarm follows them, and the appearance of the fractals will change every 30 seconds according to interpreted changes in their emotional states.

The use of fractals to represent emotion was informed by a body of cognitive psychology literature documenting aesthetic appraisal and emotional reactions to fractals [2,12]. Prior work using drones to communicate emotion and natural swarming behavior, has demonstrated how flight path and speed can be used to convey specific emotions [3,4]. Neo-Noumena takes these findings into consideration by modulating the movement speed of fractals, as well as the cohesion, avoidance and alignment of fractal swarms to reflect the emotional experience of the participant.

Demonstration

In our demonstration, pairs of participants, each fitted with their own Neo-Noumena system, will be given 5 minutes of time with Neo-Noumena. The demonstration will take place within the booth provided in the conference hall, which will contain several objects that participants may use to assist them to engage with their emotions. These objects will include: a deck of cards; headphones for listening to music; paper and pencils, pens, for writing or drawing. These objects were chosen for their easy usage and inspired by participant recounts of particularly profound moments when using Neo-Noumena in an earlier study.

This demonstration is complementary to the accepted article "Neo-Noumena: Augmenting Emotion Communication" [10]. In this submission, an 'in the wild study' of Neo-Noumena was conducted wherein five participant dyads were given Neo-Noumena to use at will for a period of three days. From this study, it was learnt that the system facilitated experiences of emotion as tangibly malleable, as objectively appreciable, and as a form of preternatural communication. Participants also reported feeling more capable of regulating others' emotions. The proposed demonstration expands on this paper by providing the opportunity for CHI attendees to experience Neo-Noumena themselves, while also opening a line of discourse for feedback and debate on the future of augmented emotion communication systems.

Conclusion

In this paper, we argue that technology has the potential to augment emotion communication. Taking inspiration from previous systems which have used technology to represent emotion, we designed Neo-Noumena, a system employing BCI-driven procedural content generation to augment interpersonal emotion communication through mixed reality. Neo-Noumena aims to provide a technology enabled representations of emotion to enhance interpersonal communication beyond current capabilities. We hope our work guides the community towards a better understanding of designing systems to augment emotion communication.

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