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A Neurofeedback Approach to Supporting Characters in Virtual Stories

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Abstract. This paper introduces a fully-implemented Brain-Computer Interface (BCI) technique developed as an input mechanism for Interactive Narratives, based on neurofeedback (NF) of an EEG measure of prefrontal alpha asymmetry. We present the evaluation of a test system using simultaneous EEG input and recording of fMRI, with subjects watching 3D graphical animations while inside an MRI unit. Subjects were able to successfully interact through NF and modify the course of the narrative. The analysis of fMRI results confirmed selective activation of the medial prefrontal cortex.

Keywords: Interactive Narratives, Frontal EEG Asymmetry, Neurofeedback, fMRI

1. BCI and Narrative Empathy

Entertainment has become a popular application domain for Brain-Computer Interfaces, video games in particular [Plass-Oude Bos et al., 2010]. The key to a successful implementation lies in the optimal integration of physiological signals into the gameplay experience. Previous work falls into two broad categories, one involving the detection of signals related to motor control (real and imagined), and the other to a user's internal state (affective dimensions, attention, etc.). In most cases the target gameplay features are self-contained, corresponding to control in games of moderate complexity, or simple moves in more complex online games.

Our objective with this current research was to optimise the mapping between BCI input and gameplay in a more sophisticated media experience. Our target was the specific genre of interactive narrative, in which a generated story (as a real-time 3D animation) varies dynamically with the user's response. We wanted to develop a unified framework that encompass (a) the user's cognitive response to a narrative; (b) an input mechanism that could be integrated with the AI generation mechanisms of the story; and (c) BCI signals that are compatible with both (a) and (b).

Several theories of media psychology (e.g., [Tan, 1996]) have posited that disposition towards story characters is a major determinant of the spectator's experience. One possible mechanism to combine this experience with user interaction thus appears to be one in which the user expresses her direct support for a character when perceiving that the character faces difficulties within a story. This has led us to explore EEG prefrontal asymmetry, as proposed by [Davidson, 1992], originally as a measure of approach/avoidance, to measure disposition towards a character. Although it has been previously mentioned as a candidate technique for BCI, to the best of our knowledge it has not been used to date in a similar context, using NF to modulate an internal state relating an external object.

2. An Interactive Narrative Experiment

We have implemented our BCI techniques within an Interactive Narrative system [Gilroy et al., 2012] that is displayed as a real-time 3D animation (developed using the UDK game engine). This is illustrated in Fig. 1. The presented story is a medical drama featuring a young female doctor as the main character, facing difficult cases as well as conflicts with colleagues. The story is dynamically generated from a set of possible *actions*, using AI Planning techniques to construct a consistent narrative progression, potentially producing in the order of a hundred variants. The default story is biased *against* that character, meaning that without user intervention the story ending will be detrimental to her. As her situation deteriorates, the system offers opportunities for the user to intervene to support her. The first opportunity is determined dynamically, but early enough in the story to be able to "rescue" her, and a second opportunity is generated soon after in case the user's first intervention is not successful.

User interaction with the system consists of prefrontal asymmetry NF, which is activated by the user mentally supporting the feature character. The feedback element is embedded in the visual appearance of the character, who fades to grey when facing difficult situations and is restored to full colour saturation following successful support.

During experimental sessions, the principles behind the interactive narrative were explained to subjects, in particular the fact that at some stages the feature character will face difficulty and that their support will be required to

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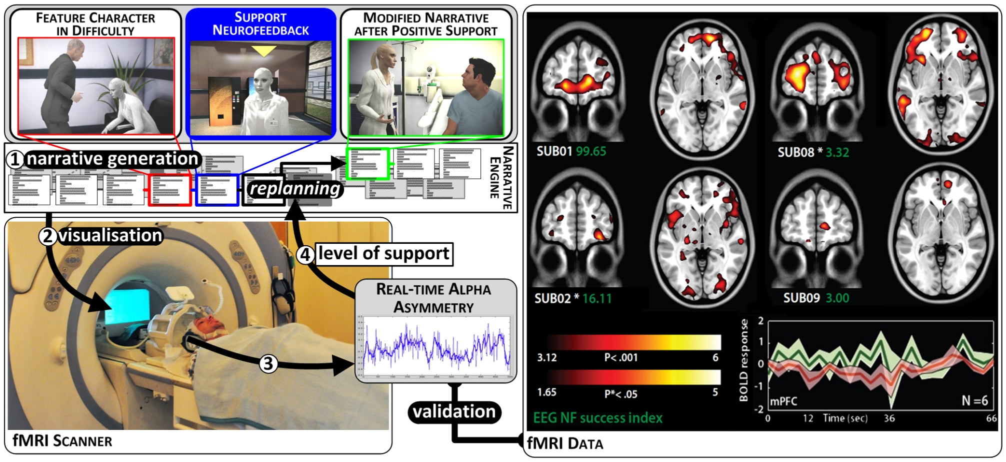

Figure 1: *Setup of NF-based Interactive Narrative experiments. A subject watches an interactive narrative from inside an MRI scanner, equipped with an fMRI-compatible EEG cap. (See main text for details.)*

enable her to overcome the difficulties. Instructions to participants remained generic such as "mentally supporting the character" or "expressing positive thoughts towards her". Subjects also underwent a specific training session that allowed them to practice NF and observe the character's response.

The experimental setup was deployed within an MRI scanner: each subject views the interactive narrative from a mirror-projected LCD screen and is equipped with an fMRI-compatible EEG cap. The subject interacts with the narrative in real-time through NF, at dynamically selected points, depending on the narrative evolution and the feature character's status. A prefrontal alpha asymmetry score is calculated in real-time from the F_3 and F_4 EEG electrodes, which is interpreted as a degree of support expressed towards the character in trouble. This score drives the evolution of the narrative, so that successful support results in a course of action that becomes favourable to the feature character.

3. Results and Discussion

Twelve users were selected for our experiments, undergoing the short training session for NF ($<$ 10 minutes, much shorter than traditionally reported in the literature) using the same virtual environment as used in the narrative, but outside of the MRI scanner. Individual measurements also allowed subject-specific calibration. The experiment was comprised of two consecutive phases: one *active* condition during which the subjects could interact with the narrative through NF, and one *control* condition during which the generated story was replayed with the interaction mechanism disabled. During the experiment, users success in supporting the feature character through NF resulted in a favourable ending for the narrative, which otherwise systematically ends with the demise of the feature character.

Of the initial 12 subjects, only 6 were able to achieve above-threshold changes in EEG alpha asymmetry during the NF phases, thus successfully altering the story. The unsuccessful subjects all completed the experiment: what they saw was simply the default story that they could not modify. We have devised a validation mechanism that compares fMRI data offline between the active and control conditions for the successful subjects, using subtraction techniques. At the anatomical level, the results were in line with our Davidsonian hypothesis, showing asymmetry as expected, with local changes of activity predominantly in the medial prefrontal cortex (Fig. 1, top right). Comparative BOLD measures during NF phases also show higher activation in the medial pre-frontal cortex for successful subjects (Fig. 1, bottom right), and little difference in activation of the premotor cortex (ruling out alternative explanations involving motor cortex activation).

These early results are certainly encouraging as a proof of concept: however, the actual usability of alpha asymmetry as an interface technique will depend on improved training methods which increase the proportion of responsive subjects without imposing lengthy, repeated training sessions.

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