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Unity Plugin for Immersive BCI Applications

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Introduction: Several groups have described BCI systems based on visual evoked potentials, including c-VEP and P300 based paradigms. In recent years, articles have drawn attention to new BCI applications with these and other BCI approaches, including immersive virtual reality (VR) for stroke rehabilitation, art, online interaction, and games [1, 2]. This represents a major shift from the conventional BCI approach, which aims to provide basic communication for people with severe motor disabilities that prevent them from communicating otherwise. However, several mechanisms for implementing BCIs in a VR have been described, and to our knowledge no plugin exists so far for the widely used Unity game engine (Unity Technologies, USA). In this paper, we introduce a new approach to BCI-based VR using the Unity game engine. It is optimized for VR development, and it contains a plugin for the Oculus VR Rift (Oculus VR, USA) head-mounted display. Thus, we developed a new plugin called screen-overlay control interface (SOCI) that combines Unity with our established BCI platform, which has already been validated with VEP BCIs [3].

Material, Methods and Results:
The plugin uses an OpenGL based flash module delivering visual stimulation for BCI applications. As shown in Fig. 1, a game object in Unity uses an instance of the SOCI display to either directly visualize a matrix on a 2D plane or to propagate flash states of BCI controls and to further assign the states to 3D game objects in the scene. To ensure proper usage of the BCI, the Unity game has to constantly run at 60 Hz refresh rate, while the integrated UDP handler in the SOCI plugin guarantees accurate trigger for a synchronous BCI. In a validation study two subjects participated in a P300 controlled simplified version of the board game Mastermind, where a 3x6 matrix was used to select color and position of a 3-digit color code. Initially, each subject performed a training run with 90 target and 540 non-target trials. Based on a training data a linear classifier (LDA) was used during the validation run, where S1 reached 100% accuracy for 8 selections with 15 trials per selection and S2 reached 100% accuracy for 8 selections with 5 trials per selection. Finally both subjects could complete the color code in an additional free run (10 selections for S1 and 5 selections for S2).

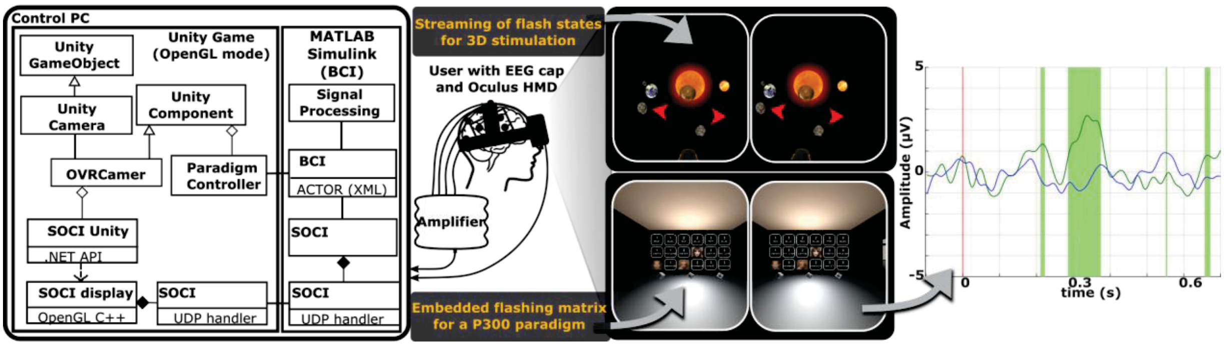

Figure 1. *Architecture of the SOCI Unity plugin (left) and stereoscopic view of two demo applications using a c-VEP (center, right) and P300 paradigm (center, bottom). On the right side the mean target (green line) P300 over Cz of S2 after 90 trials is plotted, while the green area indicates significant ($p<0.05$) deviation compared to a non-target average P300.*

Discussion: The platform described here introduces a new mechanism for developing immersive game-like environments with BCIs. Developers could easily adapt this new platform for a variety of applications to benefit different user groups. For example, we are currently testing different motor imagery BCI environments with stroke patients, and plan to explore new applications that use VEPs.

Significance: This new platform could greatly reduce development time and cost for many BCI applications, and foster development of innovative directions.

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