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Tagging Latency Estimator: A Standalone Software for Estimating Latency of Event-Related Potentials in P300-based Brain-Computer Interfaces

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Summary

Event-related potentials (ERPs) are small potentials elicited by the brain in response to an external stimulation. They are measured using an electroencephalogram (EEG). Differences in the onset time and amplitude of ERPs reflect different sensory and high-level brain processing functions, such as the recognition of symbols, the correctness of presented information, or changes in a subject's attention (Luck, 2012). For these reasons, ERPs are a useful tool for describing the processing of information inside the brain, with practical applications in the domain of brain-computer interfaces (Wolpaw & Wolpaw, 2012).

To detect and evaluate an ERP in an ongoing electroencephalogram (EEG), it is necessary to tag the EEG with the exact onset time of the stimulus. A precise hardware method is then used to assess the latency between the tag and the exact onset of the stimulus on screen (Andreev et al., 2019). This methods relies on a photodiode, placed in front of a stimulus which record the exact moment where the stimulus actually lighten on the screen. The latency is then computed by substracting the time when the EEG is tagged to the actual apparition of the stimulus on screen.

A fixed latency engenders a constant offset which can be easily removed. However, the failure to control the tagging pipeline causes problems when interpreting ERPs thus leading to contradictory conclusions (Amin et al., 2015; Käthner et al., 2015; Pegna et al., 2018) - such as confusing two ERPs. This is particulary true when comparing ERPs elicited by stimuli presented on different platforms as these platforms usually introduce latencies that differ due to specific hardware and software configurations (Cattan et al., 2021). Another common problem, is the display of stimuli that don't match the position of the photodiode. In fact, different stimuli have different latencies as different parts of the screen don't refresh at the same time.

Analysis of the tagging pipeline (Cattan et al., 2018) have led to the development of a theorical framework to interpret and eventually correct the measured latency, based on high-level configuration, such as the position of the photodiode (if known), the distribution of the stimuli on screen, the screen orientation or the number of cameras within the screen - like in virtual reality where the screen is split in two.

Statement of need

`TaggingLatencyEstimator` is a standalone software developed in Unity which provides a C# implementation for Cattan et al. (2018).

As briefly summarized in the Summary subsection, the complexity of the tagging pipeline is a problem under-estimated in the scientific literature, which could lead to the misinterpretation of the ongoing brain processing functions. It is indeed difficult to separate the latency due to software, hardware, or physiological component. This software intends to remove such biases in the analysis, by estimating the latency and variability solely due to hardware and software components.

Some of the use cases include (non-exhaustively):

- *Same experiment, different platforms*. The same visual stimulation is displayed on a PC *vs* TV monitor for example. There is a significant delay between the onset of the ERP under the two conditions. The software provides a confidence interval inside which the delay can solely be explained by the software and hardware setups.
- *Different experiments, same platform*. Two different visual stimuli, such as a word and an image are displayed on the screen. There is a significant delay between the onset of the ERPs. The software provides a confidence interval inside which the delay can solely be explained by software and hardware setup.
- *Same experiment, same platform, different runs*. A subject participates in two runs of the same experiment, consisting of the flashing of stimuli on the screen. There is a significant delay between the onset of the ERP under the two runs. The software provides a confidence interval inside which the delay can solely be explained by software and hardware setup.
- *Same experiment, same platform, same session*. A subject participates in an experiment session, consisting of the flashing of stimulation on the screen. A positive potential picks about 350ms after the onset of a stimulus, and after subtracting the latency measured by the photodiode. This potential could correspond to either a P300a or a P300b. The software estimates that an additional 50ms can be removed from the analysis due to the distribution of the stimuli on the screen. This suggests that the ERP is rather a P300a.

To our knowledge, there is no software or tools which may facilitate the correct estimation and interpretation of such latency. In addition, although this software originated from experiements with visually-induced ERPs, the principles it implements could benefit research with other types of ERP - in particular when the stimuli may appear at different locations in the same experiment, such as with spatialized songs.

Based on the model described in Cattan et al. (2018), an early version of this software was used in Korczowski et al. (2019a); Korczowski et al. (2019b); Korczowski et al. (2019c); Korczowski et al. (2019d); Vaineau et al. (2019); Van Veen et al. (2019); Cattan (2019); Cattan et al. (2021) thereby outlining the need for such an implementation.

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