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# The contribution of counting to neural activity evoked by the oddball paradigm

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*Introduction:* Research about brain computer interfacing (BCI) has shown that it can be estimated based on EEG data which stimuli a person paid particular attention to (e.g. [1]). In typical BCI experiments that use the oddball paradigm [2], several classes of stimuli are presented in succession and the stimuli of interest *(targets)* are counted while other stimuli are ignored *(distractors)*. The question was addressed if the neural activity evoked by targets is merely a correlate of the silent counting or indeed of the attention itself.
*Material, Methods and Results:* Three task variations of the oddball paradigm were compared (Fig. 1, left). Only stimuli of the ***target*** colour (indicated at the beginning) had to be counted in condition **T**. In condition **A**, summation had to be performed for ***all*** stimuli (+10 had to be added for targets and +1 for the more frequent distractors). No silent counting was performed in condition **P** where the ***positions*** of the targets on the screen had to be memorised. Thirteen persons performed each task twenty times while EEG signals were recorded with 64 active electrodes. The dynamics of the neural activity evoked by the flashing of targets and distractors were characterised (Fig. 1, center). Support vector machines were trained on the data of each condition to discriminate between single-trial EEG epochs aligned to the flashing of targets vs. distractors using spatio-temporal features and tested on separate data [3]. Training and testing was performed on all possible pair-wise combinations of the conditions (Fig. 1, right). If training and testing condition were the same, cross-validation results are reported.

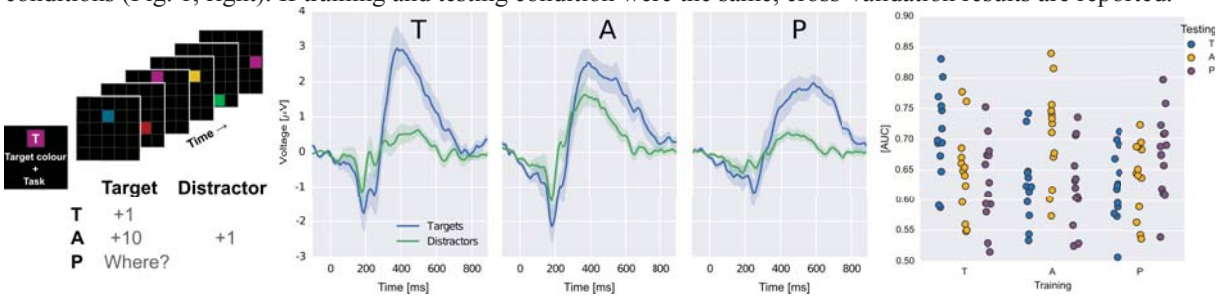


***Figure 1.*** *Left: The stimuli were the same in the three task variations T, A and P of the oddball paradigm. Squares of different colours flashed for 500 ms each, interleaved by 500 ms blank screen, in a 5 x 5 grid in pseudo-random order (short example). Center: EEG responses to targets and distractors at the exemplary electrode Pz (averages over all epochs of all subjects). Right: Classification performances of all subjects (dots) as area under the curve of the receiver-operator characteristic.*

*Discussion:* Targets evoked a larger late positive component than distractors in all three experimental conditions in particular at parietal and central electrodes (Fig. 1, center) – as it can be expected in the oddball paradigm [2]. Classification performance was better than chance (AUC of 0.5) for all combinations of training and testing condition and every subject (Fig. 1, right). Discrimination based on EEG data was also possible when both targets and distractors required silent summation (A) or when no counting was performed (P) and, therefore, counting only targets (T) was not a necessary prerequisite to elicit the characteristic neural response. The successful transfer of the classifiers between the experimental conditions suggests that the neural processing is similar. Apparently, a substantial part of the neural activity evoked by targets is indeed a correlate of the attention itself and not of the silent counting.
*Significance:* Background of the study is the objective to widen the range of application of BCI and to transfer the technology to relevance detection in human-computer interaction (HCI). EEG data could be used to predict to which items displayed on the screen a user paid special attention to. This information about the user interest could serve as additional input to computer software. Transferring BCI to HCI is presumably most useful and convenient for the user if the relevance information is inferred implicitly. For this reason, it is crucial for realistic HCI application scenarios that relevant items do not have to be counted (while in most BCI applications silent counting would be legitimate to enhance performance). We could show that counting is not necessary to detect the stimuli of interest. While single stimuli popped up in succession here, the combination of EEG with an eye tracker would allow to relate the neural activity to each of several items displayed in parallel on the screen [4].
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