EEG correlates of decision confidence in feedback processing

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Introduction:
Making decisions is part of daily life. What kind of decisions we make is often based on the level of confidence we have, or in other words how sure we are about the facts related to the decision. But investigation of decision confidence is difficult, as level of confidence influences the speed with which decisions are made, the outcome of future decision, the likelihood of making errors and thereby results can easily be confounded. Many aspects have been investigated with respect to decision confidence so far, but the field is very diverse leaving many questions still unanswered. A plain evaluation of different levels of confidence during judgement of knowing decisions was the focus of the here presented study. The main question was to investigate if differences in the neural correlates related to feedback processing can be found based on the level of confidence with which the decision was made.

Material, Methods and Results:
The study at hand is based on a study originally performed by Woodman and Fukuda [1]. A series of pictures is presented in a study phase and in a test phase. The subjects were asked to memorize as many pictures as possible in the study phase and to decide if a picture has already been seen or is entirely new in the test phase. A series of 750 pictures was presented in the test phase from which all 500 pictures from the study phase were presented again and 250 new ones, in a completely randomized order. In addition to categorizing the picture as new or already known a level of confidence needs to be specified with which the answer is given (100% or 75%). After entering the answer, the subject received a categorical feedback stating if the answer was correct or wrong. EEG data of 10 healthy subjects was recorded with a 32 electrode Brainproducts Acticap system. Classical ERP analysis was performed and a SVM based classification approach was used to reveal differences in the EEG signals between the levels of confidence throughout the feedback phase of the experiment. A Wilcoxon ranksum test (Bonferroni corrected) was used to reveal statistical significant differences. For classification the CCA filtered data of 21 channels was used (*3, *z, *4 positions) and a 1.25 second time frame throughout a 10-fold cross-validation.

The subjects categorized 64 % of all pictures correctly as new or already known. 44 % of the correct answers were given with 100 % confidence, 19 % of the answers with a confidence of 75 %. For the wrong answers the distribution was 16 % and 20 % (for the levels 100 and 75% respectively). Figure 1 shows the ERPs during the feedback phase at electrode position Cz (D) and Pz (D) of the two levels of confidence. It can be seen, that several areas within the 1.25 s time frame differ significantly between the two levels of confidence (p < 0.05). Classification revealed that a distinction of the confidence level based on the ERPs is possible with an accuracy of 69.63 %.
**Figure 1.** A shows the stimulus timing in the study phase and B stimulus timing in the test phase of the experiment. The blue circle indicates that the buttons on the left side should be used to answer if the picture is known. The yellow circle indicates that the buttons on the right should be used to answer if the picture is new. Figure 1 C shows the ERP for electrode position Cz during feedback presentation and Figure 1 D the same for position Pz.

**Discussion:**
The two levels of confidence (100% and 75%) can be distinguished based on ERPs during feedback presentation. The self-assessment of the current progress in learning is an important marker for deciding when a specific content has been learned sufficiently well. Being able to extract and identify content that is not entirely secured in memory could be beneficial for the process of learning. Content which cannot be recapitulated with a high confidence could be repeated until the subject reaches a higher confidence during answering the question related to the content. This would be a useful extension to error adaptive learning systems, that would only represent the content that has not been learned at all.

**Significance:**
Differences in neural correlates during feedback processing can be found based on the level of confidence with which the answer was given, independent of the correctness of the answer.

**References**