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WORKING MEMORY AND THE ERN: A PECULIAR RELATIONSHIP

Shaylie Platten (Sara LoTemplio)
Department of Psychology

Knowledge about our cognition is interesting in its own right. To think about how we think and to learn about how we learn is one of the ways in which we know ourselves. The present study will discuss t how our brain processes errors. More specifically, we will discuss what the ERN is, what it means, and how that relates to our working memory. Researchers know that working memory and the ERN are related, and there are some theories to explain why, but there is a lot of unanswered questions. It is in this paper I will describe what Error-Related Negativity and working memory are, their relationship with one another, and why that relationship is important. I will also discuss the study we conducted to replicate and extend findings from an earlier paper published (Coleman, 2018).

The Error-Related Negativity (a.k.a. The ERN) is a negative deflection in the EEG waveform that occurs in response to errors. The ERN was first discovered by a researcher named Michael Falkenstein in Germany (1989). Dr. Falkenstein's work was later confirmed by researchers Gehring et al. in America (1993). The ERN is still investigated and researched to this day because of how little we know about it. One main theory I will introduce here is that the ERN helps us realize errors that are threatening, keeping us safe from making dangerous mistakes again. (Gehring, et. al. 1993.) This theory explains the ERN as a way to compensate for worrying in individuals with anxiety disorders, specifically OCD, meaning that the ERN exists to help our brains cope with large amounts of worrying thoughts. Some scientists argue that this is because the ERN is used for threat detection and anxious individuals are hyper-sensitive to what could be perceived as threats.

We also know that we have a larger ERN amplitude when accuracy is stressed to be of importance. For example, in a study conducted by Gehring et al. 1993, they found that participants would produce larger ERNs under conditions when accuracy was stressed. (Gehring, 1993 pg. 385-390) Motivating participants to care about making errors is a go-to way to capture large ERN amplitudes for our studies. How we do this will be discussed later on in this article.

Working memory is another player in this equation and there appears to be a strong relationship between the ERN amplitude and working memory capacity. A good way to think about working memory is to compare it to random access memory in a computer. Its purpose is to keep information for short-term usage and then discard it when we no longer need it. Working memory is crucial for learning, cognitive processing, language, and logic! (Lotfi, Salahadin, & Richard T Ward 2020) The working memory has a main component called the central executive. The central executive is in charge of attention control. It's really important in things like chess, which is a game based on logic and pattern-seeking. This area of the working memory is susceptible to Alzheimer's disease. (Lotfi, S. et. al., 2021). The working memory is an important component in our daily lives and affects our cognition.

Indeed, working memory and the ERN are related. Prior literature has suggested that the working memory capacity influences the ERN. In other words, trait-level working memory capacity influences the amplitude of the ERN. Coleman, Watson, and Strayer used the OSPAN task to measure working memory capacity in their 2018 study. (Coleman, et. al. 2018, Miller et al., 2012) They found that working memory capacity influenced the ERN amplitude by having a more negative deflection.

Yet, all previous studies used the OSPAN task to assess this. Therefore, we wanted to replicate these findings using a different working memory task, called the Sternberg task. This way we can contribute to the scientific process and literature about the relationship between Working Memory and the ERN! We do not yet know for certain why these variables are related. In the study we set out to add to the literature and debate of what causes the relationship between the ERN and the Working Memory. My hypothesis is that individuals with larger working memory capacity will exhibit larger ERNs.

METHODS

The overall number of our participants with usable data collected was 54. Out of those 54, 37 self-identified as female, 16 as male, and 1 as non-binary. Racially, out of our 54 participants, 42 identified as White, 2 Asian, 7 Latinx, and 3 Multi-racial.

In the study that we conducted, we recorded participants' brain activity using an EEG cap. The overall flow of this study starts with a brief screening of participants, which includes consent documentation, and EEG capping. The second half of the study includes the Sternberg and flanker tasks. The EEG cap looks like a white bonnet with holes where the electrodes sit. The electrodes themselves are all connected to a box with a ribbon wire that connects to our amplifiers. We slide electrodes into the cap using plastic holders. In order for the electrodes to properly read the electrical signals on the scalp we use a conducting gel and lightly exfoliate the scalp.

In the second half of our study, participants completed 24 blocks of the Flanker task, with 50 trials in each of the blocks, sandwiched within a Sternberg task. The Flanker task requires that people make speeded judgments about a stimulus by pressing a button. Critically, ‘flanking’ stimuli are included to the left and right of the central stimulus that participants must ignore. In some trials, the flanking and target stimuli are the same (e.g., HH**H**HH) and in other trials, the flanking stimuli are incompatible (e.g., SS**H**SS). Incompatible trials are more difficult and tend to generate more errors. Participants performed two blocks of 12 rounds of the tasks (50 trials each). Before each block, for the Sternberg portion of the task, participants were asked to remember a certain number of letters in order to recall them later (see figure 1). Difficulty is based on how many letters the participant is required to remember. In our study, there were two conditions, easy (2 letters to recall) and hard Sternberg (5 letters to recall). We scored the Sternberg scores by percentage of total correct letters recalled across all blocks. We used a regression to test our hypothesis that high working memory scores would predict larger ERN amplitudes.

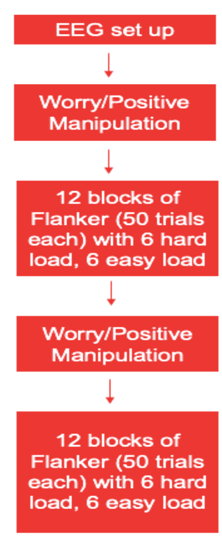
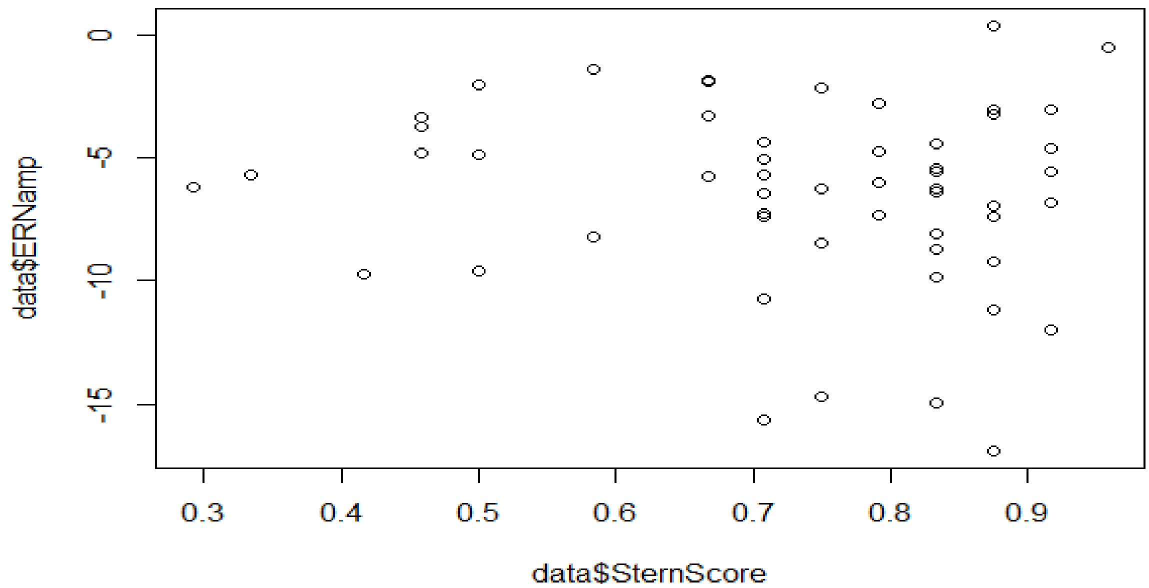


figure 1

RESULTS

A simple linear regression was calculated to predict the ERN based on the Sternberg percentage of total correct letters recalled across all blocks. A nonsignificant regression equation was found ($\beta=-4.517$, $SE=2.405$, $df=52$, $t=0.6595$, $p>0.4204$), with an $R2$ of 0.01252



DISCUSSION

In our present study discussed here, we tried to replicate an earlier study (Coleman, 2018) with the exception of using a Sternberg task instead of the OSPAN to test working memory capacity. We had expected to find similar results and reinforce these researchers' findings with our own. Instead, we found that there was no statistical significance between the Sternberg scores (working memory capacity) and the amplitudes of the ERNs recorded. There are some factors that could have contributed to our results.

One, we had interwoven the Sternberg and flanker tasks, which could have influenced our results. We do not yet know what the individual results would be of a Sternberg task, so adding a Sternberg task on the ends of the flanker task has unknown variables that could possibly affect the ERN recorded.

Two, as I have mentioned above, we have not yet experimented with the Sternberg task itself to see its effects on the ERN. There could be some unknown, confounding variables associated with the Sternberg task itself that would influence the ERN amplitudes.

Thirdly, we also had a worry manipulation tacked onto our Sternberg and flanker tasks. Worry can also influence working memory capacity (Moran, 2016) This means we were loading working memory while also having participants perform interwoven tasks. This adds another variable that could use some further exploring on its own as we do not fully know how loading working memory with a worry manipulation influences the ERN.

Finally, there is our sample size. In statistics and experiments it is worthwhile to look at sample sizes. In our case our sample size could have contributed to our null results because of its size– we may have been underpowered to look at our effects of interest. Our sample size also had very little diversity. For future experiments, singling out the Sternberg task by performing it before any other task and observing how that task itself affects an ERN amplitude will be helpful. I recommend as well larger sample sizes and no manipulations if this path is pursued.

CONCLUSION

The relationship between the ERN and working memory has resulted in many unanswered questions. Our study had hypothesized that if individuals have larger working memory capacities, then they will have larger ERN amplitudes, then we would observe and record larger ERN amplitudes. From performing a simple linear regression, we had found that our results held no statistical significance. While it would be a lie to say the results weren't a little disappointing, there is no reason for low morale. Adding to the scientific literature- positive results or not- is why we pursue these questions. It is the joy of discovery. We have many avenues to walk down now and can answer even more questions that came up during the conclusion of this study. How does the Sternberg itself affect the ERN? Does the worry manipulation and/or sample size issue influence our results? For now, we do not know the answer to these questions.