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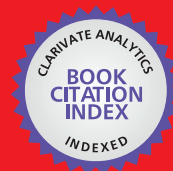
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Chapter

Mindsets and Failures: Neural Differences in Reactions to Mistakes among Second-Grade Finnish Girls

Ita Puusepp, Tuisku Tammi, Minna Huotilainen, Teija Kujala, Elina Kuusisto, Sonja Laine and Kirsi Tirri

Abstract

Mindsets have been identified as an important factor in explaining learning differences among students. Growth mindset students have been shown to recover from mistakes easier than fixed mindset students, and recent neuroscientific research has shown differences in the brain's event-related potentials to errors in fixed and growth mindset participants. The purpose of this study was to examine and evaluate these differences in the Finnish elementary school context. To achieve this, event-related potentials of ten 8-9-year-old female students, five of them with a fixed mindset and five with a growth mindset, were recorded during a go/no-go task. Differences between the two groups emerged; however, they were different from the results of some previous studies in the field. These findings are discussed in the light of earlier neuroscientific research related to mindsets, including limitations and suggestions for future research in the field.

Keywords: mindset, implicit belief, education, error monitoring, event-related potential, error-related negativity, error-related positivity, Finland, elementary school

1. Introduction

In this chapter, mindsets and differences in the neural mechanisms of attention allocation and other automatic reactions to errors between fixed and growth mindset students are discussed. The chapter presents results from a pilot study examining and evaluating these differences among girls in the Finnish elementary school context. These findings are discussed in the light of previous neuroscience research related to mindsets, including limitations of the studies conducted so far and suggestions for future research in this field.

Mindsets are implicit beliefs individuals hold about the malleability of basic qualities and abilities. People with a fixed mindset (the entity theory) believe human qualities are static; those with a growth mindset (the incremental theory) believe basic qualities can be developed [1]. The theory about mindsets helps us understand how people make sense of the world and their experiences [2].

The theory can, for example, help us understand individual differences in goal pursuit, self-regulation, and response to feedback and setbacks by shedding light on how people construct meaning, interpret their experiences, and respond to their world. Indeed, there is a growing literature describing the connections between different mindsets to different behaviors and outcomes (e.g., see [3, 4]).

Mindsets are also highly relevant when it comes to the educational context. Indeed, in the last decades, they have been identified as an important factor in explaining learning differences among students [5]. Moreover, they seem to be especially relevant in certain academic domains, such as mathematics [6, 7]. Mathematics seems to be a subject about which people tend to hold more of a fixed mindset when compared to other educational subjects [6, 8]. Indeed, compared to achievement in social science and other subjects, achievement in mathematics is often believed to depend more on an innate ability that is uncontrollable [8]. Interestingly, holding a growth mindset about mathematical ability seems to be especially beneficial for girls when compared to boys, leading to higher grades in math [9]. Thus, as growth and fixed mindsets seem to be differentially related to the students' academic outcomes, the effort they put into learning, and the way students cope with setbacks and failures, it is highly important to consider and address mindsets in the educational context [7, 10–12].

In order to shed more light on mindsets and how they affect behavior, there has, in the recent years, been a growing interest in understanding the mechanisms behind the relations between mindsets and behavioral outcomes, including interest in the possible neural mechanisms that are involved in these processes [13–17]. Indeed, individuals with a growth mindset tend to recover from setbacks easier than individuals with a fixed mindset, and neural activity concerning automatic reactions to errors seems to be involved in this ability to rebound from mistakes (for review, see [18]). Although, thus far the neuroscientific research related to mindsets is still rather scarce, especially concerning studies conducted on children. We found only two studies connecting neuroscience and the theory of mindsets, which have focused on children [15, 17].

Most of the neuroscientific studies on mindsets have examined the connections between mindsets and electroencephalogram (EEG) recordings, more specifically the connections between mindsets and event-related potentials (ERPs) [13, 14, 16, 17]. Mangels and colleagues [13] had the participants of the study answer general knowledge questions and used EEG recordings to measure their neural responses to the feedback for the questions. In other studies [14, 16, 17], the researchers used a go/no-go or Flanker's task and measured the participants' neural responses to errors. All of these studies showed differences in the neural mechanisms, more specifically in the ERPs, of fixed and growth mindset participants, which might reflect differences in the processing of errors and feedback between fixed- and growth-minded participants. More specifically, researchers [14, 17] have found growth mindset to be related to an enhanced amplitude of the error-related positivity (Pe) component of ERPs, with no differences in the amplitude of error-related negativity (ERN). In study [13], growth and fixed mindset participants differentiated in the anterior frontal P3 to negative performance-relevant feedback, which might refer to negative feedback having a stronger affective effect in the case of a fixed mindset. In study [16] P3 amplitude was larger, and late Pe amplitude was smaller in participants with an induced growth mindset when compared to the participants with an induced fixed mindset. In addition to the studies using EEG recordings, there are two studies that have used functional magnetic resonance imaging (fMRI) to explore the neural mechanisms connected to mindsets [15, 19].

At the same time, even though these neural differences between growth and fixed mindset have been shown to be present among undergraduates and children
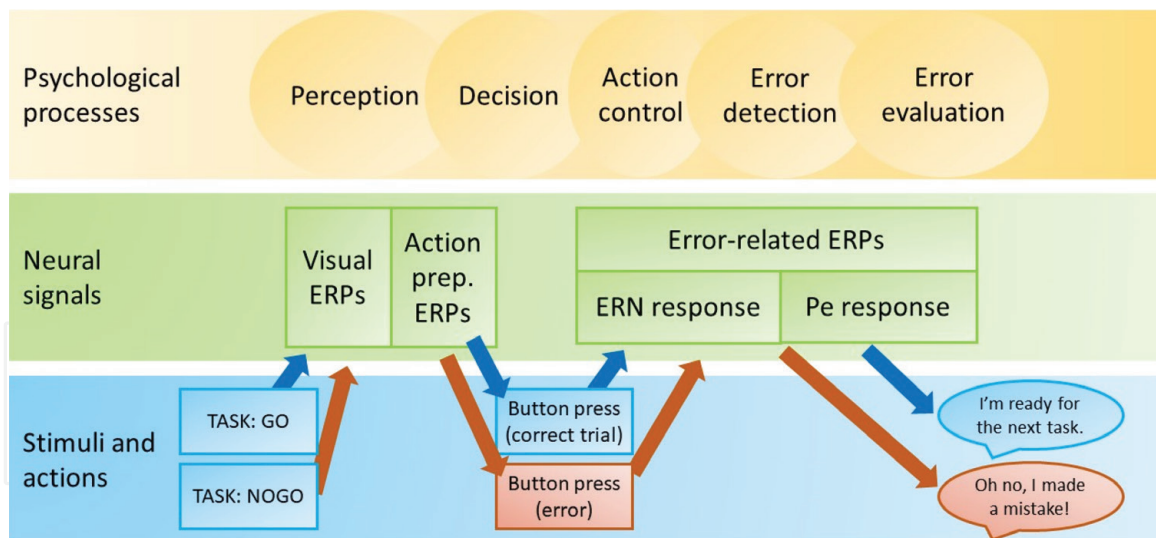
Figure 1.
Visual representation of the research design.

in North America, we found only one neuroscientific study on mindsets that has addressed different cultural contexts [19]. This study focused on mindsets about emotion regulation and not about intelligence. Still, results from that study and other previous raise questions about the cultural dependency and context of mindsets and their relations and, thus, point to the need for research on mindsets also in different cultural contexts [7, 20, 21]. This discussion illustrates the importance of investigating mindsets and their neural mechanisms also in different cultural contexts.

Taking into account the previous discussion and the stated importance of connecting psychological, educational, and neuroscientific research when studying mindsets [18], the purpose of our pilot study was to examine and evaluate the neural differences of attention allocation to mistakes between growth and fixed mindset girls in the Finnish elementary school context. Relying on the previous research in this field, we expected to detect differences in the error-monitoring ERPs of growth and fixed mindset participants. For this ERN and Pe were recorded. ERN has been associated with immediate, perhaps unconscious, error-correction or simply conflict-detection processes [22, 23]. Pe has been associated with conscious error awareness, attention allocation to errors [22], and conscious processing of motivationally significant events [24]. It has been suggested that Pe possibly reflects a subjective emotional error assessment process, which could be modulated by the individual significance of the error [23, 25]. As can be seen in **Figure 1**, at the psychological level, we assume that several processes take place, related to perceiving the task, making decision about the response, performing the action, detecting whether the action was right or wrong, and, finally, in the case of an error, evaluating the error and its consequences. At the level of the neural signals or ERPs, we can measure responses related to visual perception and action preparation (not reported in this study due to the averaging according to button press), the Pe response and the ERN response. These responses depend on the task (go trial or no-go trial), the action (button pressed or not pressed), and the correctness of the button press and are expected to also depend on the mindset of the participant.

2. Methods

Participants of the study were 10 right-handed second-grade female students aged 8–9 years (mean = 8.50, SD = 0.53). All of the participants were native Finnish

speakers and students from a Finnish public elementary school, namely, the Viikki Teacher Training School of the University of Helsinki, where the student teachers practice under the guidance of mentors who are highly skilled in teaching. Additionally, research, practice, and development activities have a crucial role in Viikki Teacher Training School. The school has learning resources available for different learners with advanced pedagogies in use. Elementary school students in Viikki School are in general local children from the neighborhood, which can be described as a medium socioeconomic status district when compared to other areas in Helsinki [26].

The students' participation in this pilot study was voluntary, and parental, school principal, and municipal officials' written consents were obtained. The study was part of a bigger research project, which had already been reviewed and approved by University of Helsinki Ethical Review Board before. The participants had the right to cancel their participation at any moment of the study and measurements.

Participants had previously been classified as growth or fixed mindset students in the following manner: during individual interviews a researcher had asked the students 10 questions of a 5-point Likert-type scale questionnaire based on Gunderson and colleagues' mindset questionnaire used among children in previous research [27, 28]. They were also asked to describe how they understand the words "intelligence" and "giftedness." During that interview the participants were encouraged to bring up examples or questions related to the questionnaire.

The experiment was conducted by two experimenters during the school day in a separate space at the school premises. Before the experiment, the students were briefed about the process; they were encouraged to ask questions about the experiment and were reminded that they can cancel their participation at any moment. Participants then completed the task on a laptop. After the task, participants were debriefed about the experiment and compensated. The whole procedure lasted for approximately 1 h per participant.

The task was an age-appropriate go/no-go task adapted from Grammer and colleagues' study [29]. Participants were told that the task was a game in which they had to help a zookeeper catch animals and were instructed to press a button every time they saw a picture of an animal (go trial) except when the animal was an orangutan (no-go trial), because orangutans were also helping the zookeeper. The task consisted of a practice block (9 go trials, 3 no-go trials) followed by 16 blocks (30 go trials, 10 no-go trials) making up a total of 640 trials. Each stimulus was presented for 750 ms followed by a blank screen for 500 ms (response window 1250 ms). The participants were allowed small breaks between blocks and a longer one between blocks 8 and 9.

The task was conducted with presentation software (Neurobehavioral Systems, Inc., Albany, CA). EEG data were recorded with portable equipment (BrainVision QuickAmp amplifier) using 32 Ag-AgCl active electrodes (ActiCap, Brain Products, Germany) including two mastoid electrodes, one nose and one vertical eye movement electrode. Electrolyte gel (Signa Gel, Bio-Medical Instruments, Inc., Warren, MI) was used at each electrode. The data were recorded with BrainVision Recorder at 500 Hz sampling rate.

After recording, the EEG data were processed with Matlab R2017b software (Mathworks, Natick, MA) with EEGLAB 14.1.2b toolbox. The signal was high-pass filtered at 0.1 Hz and epoched 1250 ms before and 500 ms after response. In addition to visual inspection, artifactual epochs were rejected by detecting abnormal trends and abnormal spectra, and eye movement artifacts were removed using independent component analysis (ICA) [30]. The data were re-referenced to the average of the two mastoid electrodes. Response-locked grand average ERPs for

channels Fz and Pz were calculated and baseline corrected by subtracting the mean amplitude from −150 to −50 ms pre-response. For figures, the waveforms were low-pass filtered using a Butterworth filter of order 3 with a cutoff frequency of 30 Hz.

Behavioral data from the go/no-go task included response accuracy and reaction time measures for each trial. These were further processed in R statistical software (version 3.4.3) and used to compute measures for post-error adjustments, following Moser and colleagues [14].

3. Results

The responses to correct trials and error trials differed in both groups. Moreover, as expected, differences of error-monitoring ERPs between growth and fixed mindset students emerged, suggesting different attention allocation to mistakes, which is believed to play an important role in bouncing back after failure (**Figure 2**). It can be seen from the data that the difference curve calculated between the correct and error trials was larger in children with fixed mindset when compared to children with growth mindset. In the frontal areas (observed at Fz channel) in the early latencies 100–200 ms after response (the button press), the ERN amplitude (calculated as the difference between positivity on error trials and relative to that on correct trials, see **Figure 3**) is larger in the children with fixed mindset. There is no difference in the shape or timing of the ERN response in the two groups.

The data also show clear differences between the groups in the Pe component, the difference signal calculated between the correct and the error trials in the parietal electrodes (observed at Pz channel) in later latencies (200–500 ms after response). Fixed mindset was associated with larger Pe difference than growth mindset.
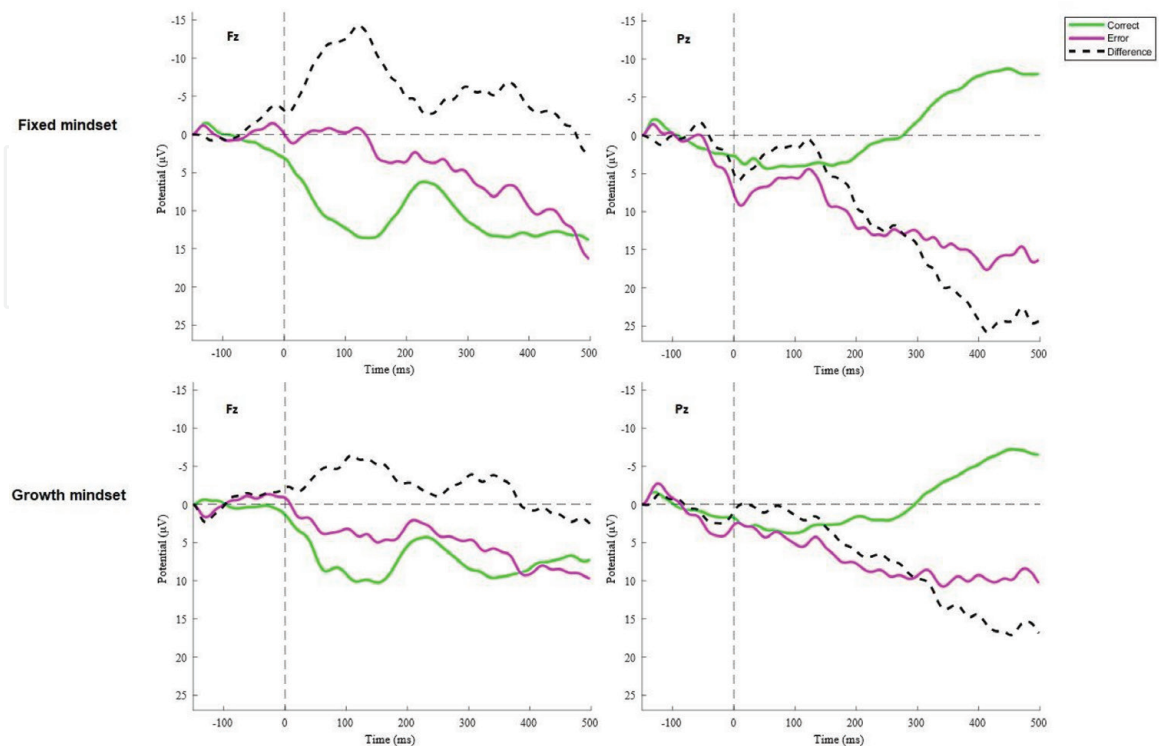

Figure 2.
Response-locked waveforms for correct and error trials in fixed (upper panel) and growth mindset groups (lower panel) at frontal Fz (left) and parietal Pz (right) electrodes.
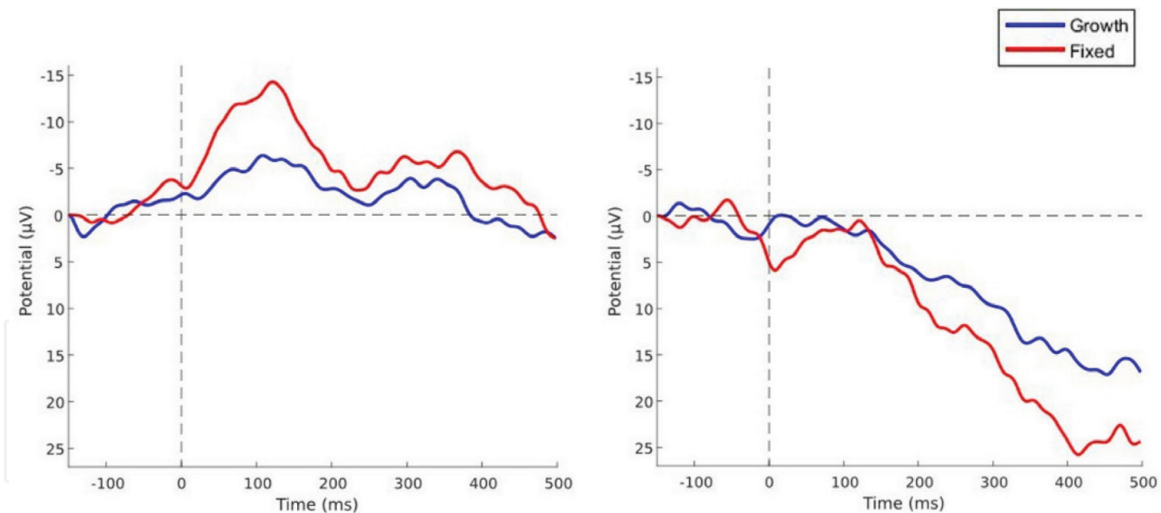
Figure 3.
Response-locked subtraction signals in fixed and growth mindset groups at frontal Fz (left) and parietal Pz (right) electrodes. Here, response to correct trials is subtracted from the response to the error trials.

At the behavioral level, growth mindset participants showed decreased post-error accuracy, meaning that they got less correct responses on trials following error hits than on trials following correct hits; this was opposite for the fixed mindset group. There was no considerable difference in post-error reaction times, but overall reaction times were shorter for the fixed mindset group, especially in error trials. Fixed mindset participants also made less error hits and more correct hits, i.e., their overall performance was slightly better. This is in line with results by Torpey et al. [31], who found that a more positive Pe is associated with greater accuracy and shorter reaction time in error trials. Overall, these results suggest that participants with a fixed mindset responded faster and, while allocating attention to errors, did not show improvement/adjustment in behavioral terms, such as post-error slowing.

4. Discussion

This pilot study contributes to the international mindset research by testing the mindset theory and experimental design, previously used in North America, in the Finnish context. It also provides evidence for differences in the neural mechanisms of attention allocation and in automatic reactions to errors between individuals with growth and fixed mindsets. Namely, in this study, the ERN amplitude was larger in the children with fixed mindset. Large ERN can be interpreted as more neural resources allocated to the detection of the error and also the further processing after detecting the error [32]. In addition to this, fixed mindset was also associated with larger Pe difference than growth mindset. These responses may reflect further processing of the errors, recovery after the errors, and reallocation of attentional resources to avoid future errors [33]. This suggests that fixed mindset children in this pilot study seem to invest a lot of effort in processing their errors and reorienting after the error has occurred. Growth mindset students also showed decreased post-error accuracy, while this was opposite for the fixed mindset group.

Interestingly, even though clear differences between the two groups emerged, these findings are somewhat inconsistent with the results from previously conducted research in North America [14, 17]. Namely, researchers [14, 17] have found growth mindset to be related to an enhanced amplitude of the Pe and better accuracy after mistakes, but not to ERN. Thus, the findings on the amplitude of Pe and

also post-error accuracy were strikingly different from the findings from the North American studies. In addition to this, in this pilot study, differences in ERN were found, while this did not differentiate between growth and fixed mindset participants in the North American studies.

One possible explanation for this difference in the results of this pilot study, when compared to previous studies, is the young age of the participants. Namely, ERN seems to fluctuate during development [34]. Consistent with this, researchers [35] showed in their study that in younger children (8-to-10-year-old), a smaller ERN related to parent-reported anxiety, whereas in older children (11–13-year-olds), a larger ERN was significantly related to anxiety [35]. Consequently, the authors of the mentioned study discussed that it is possible that the relationship between increased error-related brain activity and anxiety may not emerge before early adolescence. Thus, one could speculate that it might be the same regarding the relationship between ERN and mindsets.

When discussing the differences between the results concerning Pe in this pilot study and previous studies, it is worth to mention that also Schroder and colleagues [17] showed that more attention allocation to errors (Pe) is not necessary for growth mindset children to recover from mistakes. Indeed, they did not find Pe to have the mediating role in recovering from mistakes as it had for grown-ups in the study conducted by Moser and colleagues [14]. Also the correlation found between growth mindset and Pe in study [17] on children was rather modest, and there were actually many growth mindset children who had average or below average Pe amplitudes. In addition to this, even though there is a difference in the time windows when compared to the current pilot study, in study [16] Schroder and colleagues found no differences in the early Pe (150–350 ms post-response time window) but found a smaller late Pe (350–750 ms post-response time window) amplitude in adult participants with an induced growth mindset when compared to the participants with an induced fixed mindset. Even though Pe has been shown not to have a similar age-related fluctuation as ERN [34], the inconsistencies of these findings might refer to other mechanisms involved in the processes of dealing with mistakes related to mindsets. Indeed, Meyer and colleagues also showed that smaller Pe amplitude related to greater parent-reported anxiety only among older children, with younger children's anxiety level having no significant effect on Pe [35]. Thus, taking into account the mentioned research concerning ERPs, it is possible to speculate that as the ERN fluctuates during development, a clearer relationship between increased error-related activity and mindset also may possibly not emerge before early adolescence, at least concerning ERN. The findings on Pe in this study, though, are somewhat controversial when compared to other studies and require further research on the developmental processes involved in error-related brain activity and mindsets, as the results suggest that there might be other mechanisms involved in the processes of dealing with mistakes when it comes to mindsets. Thus, in the future it would be important to conduct more research on the neural mechanisms related to mindsets among different age groups, including more participants and including both boys and girls as the current pilot study had a small sample size and only included girls as participants. Moreover, it would also be important to include participants from different schools and possibly more diverse socioeconomic backgrounds.

In addition to this, the results of this pilot study might differ from the previous ones due to a different cultural context. As mentioned in the first part of this chapter, there are studies that refer to possible culture- and context-dependency of mindsets [7, 19–21]. Thus, it would be important to study mindsets in different cultural contexts and also conduct comparative studies investigating mindsets, their functioning, and relations to neural mechanisms.

None of the neuroscientific research concerning mindsets has taken academic-domain-specificity into account. Previous studies using EEG recordings have measured mindsets about and used a task/test addressing general intelligence [13]; measured or induced mindsets about general intelligence [14, 16, 17] and the EEG measurements have been done during a completion of a go/no-go task or a Flanker's test. Even though the mindset measurement reflects the general underlying dimension of the mindset tendency in addition to the directly reflecting the mindset about intelligence [36], it is possible to speculate that the go/no-go task or Flanker's test used might not be reflecting the domain of intelligence for the participants. As these ERPs are measured and should theoretically reflect automatic reactions to errors of a person with a growth vs. fixed mindset, the ERPs may reflect the person's implicit beliefs in another domain than intelligence, which was measured or induced in these studies. Rather one could speculate that these tests might resemble more of a computer game than a test concerning intelligence, and thus, it might be more relevant comparing these ERPs regarding a growth vs. fixed mindset about the ability to play computer games, which might be remarkably different from the mindset that the individual holds about their intelligence or other domains like mathematics. Indeed, among these studies, as mentioned above, only Mangels and colleagues [13] have used a design, where the mindset measured and task used for EEG measurements match in their domains. Namely, they used measures of theories of intelligence (TOI) and a task, which included general knowledge questions. As mindsets, though, have been shown to have such considerable relations to academic outcomes [7], one important future direction would be measuring academic-domain-specific mindsets and using tasks/tests from the matching academic domain during the EEG measurements. This would enable to study the automatic reactions to errors in the specific academic domain of the held mindset and would thus yield to theoretically more sound results. One possibility to do this would be to modify the go/no-go task or Flanker's test to be more domain-specific, for example, resembling a math test and then comparing the ERPs from this test to the participants' academic-domain-specific (math-specific in the case of this example) mindsets.

All in all, understanding the neural mechanisms related to mindsets will enable, when combined with findings from other fields of research, the planning and construction of more successful interventions to encourage growth mindset. Taking into account the underlying neural mechanisms and structures of mindsets will enable to tap into how these implicit beliefs interact with cognitive and also other higher psychological processes, in order to improve students' learning experience and results. Moreover, it will help to understand how these interactions affect behavioral outcomes not only in the academic but also a variety of other contexts.

Notes

Abbreviations

ERN	error-related negativity
ERP	event-related potential
Pe	error-related positivity

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