The Use of Information about the Foreseeable Termination of a Prolonged Task to Modulate Time on Task Effects: An ERP-Study

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Abstract

Prolonged engagement in repetitive and monotonous tasks lead to continuously declining task performance caused by mental fatigue, called Time on Task effects (ToT). Previous literature suggested that awareness of the foreseeable task termination can positively influence mental fatigue and task performance in form of a 'final spurt effect' by increasing participants' motivation. The present study aimed at verifying the use of time-related information in form of a progress bar to decrease mental fatigue and to elicit a final spurt phenomenon at a behavioral and electrophysiological level using event-related potentials and lateralizations (ERPs and ERLs). Mental fatigue was induced in 30 participants using prolonged task performance in a combined Posner cueing-task switching paradigm. Afterwards, participants rated their perceived motivation, task engagement, and mind wandering for experimental blocks either presenting or not presenting a progress bar. Although the self-reports indicated that the progress bar positively affected the participants' task engagement and motivation, this has not been translated to behavioral and electrophysiological measures except for the ADAN ERL-component. Increased response times and P3b amplitude, as well as reduced P2 and ADAN amplitudes, indicated a moderate ToT effect. However, this was not mirrored by the N2, EDAN or LDAP. The rather mixed results might be either because the progress bar was not able to sufficiently modulate ToT effects, or because interacting processes had a significant influence on ToT and final spurt effects. This could include the duration of continuous task performance, the task sets' variety, learning effects regarding task switching, and the design of the progress bar. Future studies on modulating ToT effects should account for an adapted design of the progress bar, providing more direct information about the remaining task duration, and objective measures such as eye-tracking to check participants' attention towards the progress bar.

Keywords: time-on-task, mental fatigue, motivation, final spurt, EEG, ERP, ERL.

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1 Introduction

In many everyday settings, individuals are facing situations of prolonged task execution characterized by rather low task demands and little mental effort such as, for example, in the case of a long-distance car ride on highways. Although these tasks often have to be executed on a constantly adequate performance level to ensure one's own and others' safety, repetitive and monotonous tasks have been observed to lead to continuously declining vigilance and task performance with progressing time (Arnau, Möckel, Rinkenauer, & Wascher, 2017; Boksem, Meijman, & Lorist, 2006; Ziv, 2017). The resulting increase in human errors can potentially lead to accidents, for instance driving a car off the road (Campagne, Pebayle, & Muzet, 2004). Therefore, it becomes relevant to understand the underlying factors of this performance decrease, and especially how to counteract or reduce this phenomenon. As the underlying cause, increasing mental fatigue was identified (Boksem, Meijman, & Lorist, 2005; Ziv, 2017). Previous literature suggested that subjective mental fatigue and task performance can be positively affected by increasing an individual's awareness of the remaining task duration (Bergum & Lehr, 1963; Ohrui et al., 2008). For example, Ohrui et al. (2008) reported that a pilot's awareness of an approaching landing during a long-distance flight was associated with decreasing self-rated physical and mental fatigue. Therefore, this study aims at investigating whether feedback about the foreseeable termination of a prolonged task can be used to improve task performance and vigilance in individuals.

In the following, the concept of Time on Task effects including its underlying components and behavioral correlates will be explained. Then, previous research aiming at counteracting these effects with different approaches will be discussed. Finally, relevant electrophysiological correlates of both Time on Task and modulating effects will be reviewed, and the research question with its hypotheses will be proposed.

1.1 Time on Task (ToT) effects

A decreasing task performance, characterized by increasing response times and decreasing response accuracy rates (Arnau et al., 2017; Boksem et al., 2005; Wascher et al., 2016), is a well-known phenomenon of prolonged task execution and is categorized as a negative Time on Task (ToT) effect. Although previous literature has also identified positive effects related to time-on-task, such as, for example, learning effects (Scherer, Greiff, & Hautamäki, 2015), the term ToT will in the course of this paper be associated with the negative performance deteriorating effect as described above. A rich body of research investigating ToT effects, identified increasing task-related mental fatigue as the underlying cause of the performance decline (Arnau et al., 2017; Boksem et al., 2005, 2006; Campagne et al., 2004; Dinges, 1995; Lorist, Boksem, & Ridderinkhof, 2005; Van der Linden, Frese, & Meijman, 2003). Task-related mental fatigue can be distinguished into being of passive or active nature (Hockey & Hockey, 2013). Active task-related mental fatigue is caused by cognitive overload leading to physiological resource depletion. However, passive task-related mental fatigue is caused by cognitive underload due to monotony (Hockey & Hockey, 2013; May & Baldwin, 2009) and was identified causing the above addressed ToT effects in individuals executing a prolonged, repetitive task (Arnau et al., 2017; Boksem et al., 2005, 2006; Lorist et al., 2005).

1.1.1 The underlying cause of ToT effects: vigilance decrement vs. the motivational system

Previous literature provides two opposite perspectives on the underlying cause of performance decline and passive task-related mental fatigue shown in vigilance tasks, namely the theory of vigilance decrement (Charbonnier, Roy, Bonnet, & Campagne, 2016; Epling, Russell, & Helton, 2016) vs. the role of the motivational system (see e.g., Boksem & Tops, 2008; Wascher et al., 2016).

In the theoretical model of vigilance decrement, researchers proposed a theory in which cognitive resources including attention and information processing are seen as a limited but renewable supply (Epling et al., 2016). According to this theory, task engagement continuously consumes these resources. However, if during prolonged task performance the supply of cognitive resources is being utilized faster than being restored again, this would eventually lead to resource depletion and in turn to increasing mental fatigue and decreasing task performance (Charbonnier et al., 2016).

In contrast, the second stream of previous research proposed that passive task-related mental fatigue and reduced task performance in prolonged task execution are closely connected with an individual’s motivational system (see e.g., Boksem et al., 2006; Boksem & Tops, 2008). For example, Rubinstein (2020) suggested that cognitive resource allocation is of dynamic nature. According to the author, it follows strategic pattern of systematic cognitive disengagement from a task in case the expected payoffs are low. In other words, if the expected outcome of a task is outweighed by to-be-invested resources, which is likely to occur in monotonous tasks with low predicted rewards, task engagement and the respective cognitive resource allocation decrease (Boksem et al., 2006; Boksem & Tops, 2008; Bonnefond, Doignon-Camus, Hoeft, & Dufour, 2011; Wascher et al., 2016). In line with this statement, increasing aversion to further engage with the respective task was previously found to reliably positively correlate with mental fatigue and performance decline (Grandjean, 1979; Lorist et al., 2000; Siegrist, 1996; Tops & Boksem, 2010; Van der Hulst & Geurts, 2001). In addition to the performance and motivation deteriorations, previous studies using monotonous and continuous performance tasks have found support for stronger mind wandering in individuals (Jin, Borst, & van Vugt, 2020). Mind wandering is commonly defined as self-generated thoughts that are non-oriented towards the current task (Brosowsky, DeGutis, Esterman, Smilek, & Seli, 2020; Jin et al., 2020).

Although both presented streams of research concerning the underlying cause of performance deterioration in vigilance tasks are well-founded, the theory involving the motivational system of an individual will be the object of the current research. This decision is based especially on findings of, for example, Boksem et al. (2006), Wascher et al. (2016), and Lorist et al. (2005). The authors showed that after prolonged task execution, individuals' performance and mental fatigue could be improved by increased their motivation to further engage in the task. These findings point against the theory of vigilance decrement and, thus, against deteriorated performance due to exhausted resources. The authors' approach will be explained in more detail in section *1.2 Counteracting ToT effects*.

1.1.2 Behavioral correlates of ToT effects

A well-known correlate of passive task-related mental fatigue is an increased difficulty in maintaining one's performance efficiency on an adequate level (Boksem et al., 2005; Lorist et al., 2005). The performance and vigilance decline elicited by ToT is, as mentioned above, reliably represented by increasing response times and decreasing response accuracy rates (Arnau et al., 2017; Boksem et al., 2005; Wascher et al., 2016). Task switching paradigms were found to reliably evoke mental fatigue and, thus, ToT effects, as they require continuous cognitive control (Kiesel et al., 2010; Lorist et al., 2009). In non-fatigued individuals, repetition trials (i.e., trials requiring no mental switch between task sets as the same task has to be performed on successive trials) were associated with shorter response times and less errors compared to switch trials (i.e., trials requiring a mental switch between task sets as a different task has to be performed on successive trials; Lorist et al., 2000). These effects of the trial sequence on behavioral measures are termed switch costs and are commonly held to reflect a mental reconfiguration in task-sets by mentally switching from one certain rule of stimulus-response to a different one (Rogers & Monsell, 1995). With increasing fatigue and ToT, the response times and error rates then increased in both repetition and switch trials, decreasing the initial differences (Lorist et al., 2009).

The potential explanation of the ToT effect on an individual's behavior is that one of the most vulnerable processes affected by mental fatigue is the top-down modulation of behavior (Lorist et al., 2000). Its reduction is associated with diminished control over actions, leading to limited response preparation and monitoring, as well as elevated levels of inattentiveness and distractibility (Boksem et al., 2005, 2006; Dinges, 1995; Lorist et al., 2005; Van der Linden et al., 2003). Lorist et al. (2000) argued that maintaining the mental state of a prepared response to a stimulus becomes increasingly difficult if individuals become mentally fatigued.

1.2 Counteracting ToT effects

As a fatigue-induced performance and vigilance decrement can lead to human error and potentially serious and harmful incidents in daily life, it becomes relevant to understand how to counteract ToT effects.

1.2.1 The use of motivation

Boksem et al. (2006) stated that mental fatigue can be significantly reduced by increasing an individual's motivation to further engage in a task by using incentives to improve the perceived effort-reward-balance. After 2 hours of executing a monotonous task, participants were motivated by offering monetary rewards in case of superior performance for the remainder of the session. This instruction has led to significant improvements in action monitoring, leading to increased performance and decreased error rates, approximately up to the level as when participants initially started the experiment (Boksem et al., 2006). This final increase in task performance is called the *final spurt phenomenon* and has frequently been observed (Bergum & Lehr, 1963; Boksem et al., 2005; Langner, Willmes, Chatterjee, Eickhoff, & Sturm, 2010). However, it has further been investigated in only a few isolated studies (see e.g., Bergum & Lehr, 1963; Boksem et al., 2005, 2006; Lorist et al., 2005; Wascher et al., 2016).

1.2.2 The use of time-related information as a motivational factor

Following the approach of using incentives to elicit a final performance spurt, previous literature indicates the effectiveness of providing individuals with information about the remaining duration of a task (Bergum & Lehr, 1963; Boksem et al., 2005, 2006; Lorist et al., 2005; Wascher et al., 2016). In this case, the foreseeable termination of the monotonous task displays the incentive and reinforces an individual's motivation to invest more mental effort in a task. Using a vigilance task, Bergum and Lehr (1963) found significant performance improvements in individuals being aware of the remaining task duration compared to a control group who did not receive this information. Therefore, the authors concluded that the occurrence of a final spurt phenomenon would depend on previous knowledge about the length of a prolonged task and suggested reinforced motivation as the underlying component.

However, this hypothesis would have to be tested in more detail to be confirmed, including the investigation of motivational effects on further dependent performance variables.

In order to further investigate the motivational properties underlying time-related information in prolonged task execution, Thönes, Arnau, and Wascher (2018) analyzed the influence of external clock-speed manipulations in the form of accelerated and decelerated clock presentation on perceptual, cognitive, as well as physiological parameters. The meta-analysis including 10 studies revealed that the subjective perception of time can effectively be manipulated in individuals and potentially improve cognitive performance and motivation by evoking certain cognitive and affective states (Thönes et al., 2018). However, these results raised the question whether performance increases were evoked by short-term alterations of the subjective passage of time, or by the expected proximate termination of the prolonged task. Since this question could not be answered by Thönes et al. (2018), the current study aimed at further investigating the latter mentioned potential cause of the performance increase.

1.2.3 The influence of motivation on behavioral correlates

Since a final spurt phenomenon is associated with modulating ToT effects (Boksem et al., 2006), this tendency is also expected to translate into behavioral correlates. Due to more extensive response preparation, decreasing response times and increasing response accuracy can be expected (Boksem et al., 2005, 2006; Lorist et al., 2005; Wascher et al., 2016). However, individuals seem to either focus on their response time or their response accuracy at the expense of the other one, but never on both, leading to a speed-accuracy trade-off (Boksem et al., 2005). Boksem et al. (2005) assumed that fatigued individuals focus on one performance measure to counteract the effects of reduced invested resources and to maintain an acceptable performance level. Furthermore, Lorist et al. (2009) stated that individuals who received monetary incentives, reduced their response time on switch trials to an even lower level than during the first 20 minutes of the task performance, thus, before the ToT effect had set in. This, however, was not the case for repetition trials. Thus, fatigued individuals seem to develop an internal adaptive strategy by focusing on response accuracy or speed to keep the task performance at an adequate level in the face of conflicting internal states (Boksem et al., 2005).

1.3 Electrophysiological correlates of ToT effects and final spurt phenomena

Changes at the behavioral level elicited by ToT and the final spurt effect are usually mirrored by changes in brain activity. Due to a number of reasons, electroencephalography (EEG) is a suitable measurement technique to keep track of shifts in cognitive states such as attention and vigilance (Siegel, Donner, & Engel, 2012). For instance, EEG is sufficiently sensitive to canonical neural computations that underly cognitive constructs and has a sufficient temporal resolution to keep track of changes in these (Arnau et al., 2020; Siegel et al., 2012). Another reason is that EEG is non-invasive as well as unobtrusive, therefore it does not significantly interfere with a participant’s task (Yang, Wilke, Brinkmann, Worrell, & He, 2011).

Neurophysiological signals in both the time-frequency and time-domain have been analyzed in previous literature addressing changes in prolonged vigilant attention. Regarding time-frequency analyses, a positive correlation between activity in the alpha frequency band (8 - 14 Hz) at parietal leads and mental fatigue as well as mind wandering was found with increasing ToT (Martel, Dähne, & Blankertz, 2014; Wascher, Heppner, & Hoffmann, 2014; Wascher et al., 2016). Also, changes in the theta frequency band (4 - 8 Hz) over the medial prefrontal cortex have been reported frequently, which was associated with reduced top-down information processing performance (Arnau et al., 2017; Cavanagh, Zambrano-Vazquez, & Allen, 2012; Jensen & Tesche, 2002; Onton, Delorme, & Makeig, 2005). However, the current study will focus on the time-domain of electrophysiological signals, thus, on event-related potentials (ERP) and lateralizations (ERL). Hereby, it was focused on six specific components that reflect different aspects of cognitive processes: the N2, P2, and ADAN at fronto-central brain regions (Di Russo et al., 2021; Donohue, Liotti, Perez, & Woldorff, 2012; Freunberger, Klimesch, Doppelmayr, & Höller, 2007; Swick & Turken, 2002), as well as the P3b, EDAN and LDAP at posterior brain regions (Di Russo et al., 2021; Hamamé, Cosmelli, Henriquez, & Aboitiz, 2011; Martel et al., 2014; Swick & Turken, 2002).

1.3.1 The P2 component

The P2 is a positive ERP component typically occurring over frontal brain regions around 200ms post-stimulus (Freunberger et al., 2007) and is used as a neurophysiological marker of cognitive processes involving the selection of relevant information from working memory (Evans & Federmeier, 2007; Lefebvre, Marchand, Eskes, & Connolly, 2005; Lenartowicz, Escobedo-Quiroz, & Cohen, 2010). With regards to task switching paradigms, a significant reduction in the P2 amplitude elicited by repetition trials compared to switch trials has been found, representing switch costs (Kieffaber & Hetrick, 2005). With increasing ToT, the P2 amplitude has been found to significantly decrease with increasing mental fatigue, which was associated with reduced memory performance (Liu, Zhu, Chang, Hämäläinen, & Cong, 2020; Lorist, 2008; Xiao et al., 2019). Hereby, Liu et al. (2020) has found a strong correlation between this component’s reduced amplitude and the identification of target stimuli, which is in line with previous research linking the P2 with processes of working memory information encoding (Lefebvre et al., 2005).

1.3.2 The N2 component

The N2 component is a negativity typically occurring around 220 and 300ms post-stimulus and is associated with low-level processes underlying action monitoring and top-down modulation of action control (Foucher, Otzenberger, & Gounot, 2004; Gajewski & Falkenstein, 2014). The N2 is interpreted as being an index of anterior cingulate cortex (ACC) activity (Bekker, Kenemans, & Verbaten, 2005; Cavanagh & Shackman, 2015; Conti & Nakamura-Palacios, 2014), which is involved in attentional processes, cognitive control, action selection and evaluation processes of the motivational significance of actions (Boksem, Kostermans, Tops, & De Cremer, 2012; Bush, Luu, & Posner, 2000). In accordance with the associated involvement of the ACC in action selection and control processes, studies using task switching paradigms have found a significantly larger N2 amplitude elicited by switch trials compared to repetition trials over fronto-central areas (Gajewski, Kleinsorge, & Falkenstein, 2010). In line with these findings, Cutini, Duma, and Mento (2021) identified a cluster over anterior leads displaying a strong negativity fitting the topography of the N2 associated with switch trials, therefore termed switch negativity. This switch negativity has also previously been found to be positively correlated with fMRI activity in the ACC (Botvinick, Cohen, & Carter, 2004), supporting the suggestion that the switch negativity is reflected in the N2 ERP component.

Supporting the assumption that the activity of the ACC is affected by mental fatigue, studies have shown that with increasing ToT, the N2 amplitude significantly decreases, correlating with a decrease in task performance (Boksem et al., 2005; Möckel, Beste, & Wascher, 2015; Olofsson & Polich, 2007; Pessoa, 2009). Lorist et al. (2000) reported that with increasing ToT, the amplitude for both repetition and switch trials significantly decreased, hereby reducing the initial difference between both kind of trials as switch trials were affected more strongly. Also, Cutini et al. (2021) concluded that a reduced switch negativity would reflect higher switch costs and less effective coping with the interference of multiple task sets. Therefore, the ACC function of cognitive control seems to be negatively affected by ToT and mental fatigue (Lorist et al., 2000).

1.3.3 The EDAN / ADAN / LDAP lateralization

The process of attention, however, does not only involve the detection and discrimination of target stimuli, but also includes visuospatial attention prior to the target stimulus presentation (Posner, 1980). Visuospatial attention is the attention direction towards a certain location in space, for instance as a preparatory activity in the anticipation of a discriminatory or imperative stimulus presentation (Di Russo et al., 2021; Posner, 1980). Three lateralized components with distinct topographies that are related to anticipatory visuospatial attention allocation are the early directing attention negativity (EDAN), the anterior directing attention negativity (ADAN), as well as the late directing attention positivity (LDAP). All three components occur contralateral to the direction of the attentional shift (Eimer, Forster, & Van Velzen, 2003; Eimer, Velzen, & Driver, 2002; Talsma, Slagter, Nieuwenhuis, Hage, & Kok, 2005; Van der Lubbe & Utzerath, 2013). The EDAN peaks between 150ms and 350ms over occipital-parietal regions and is associated to reflect the first phase of spatial orienting by extracting the meaning of the directional cue as well as the attention shift towards the cued side (Di Russo et al., 2021; Velzen & Eimer, 2003). The ADAN, which was first discovered by Eimer (1993), peaks between 350ms and 500ms over frontal regions and is associated with the representation of activated frontal brain regions involved in the coordination, control and holding of visuospatial attention from a top-down level (Di Russo et al., 2021; Praamstra, Boutsen, & Humphreys, 2005; Talsma et al., 2005). Lastly, the LDAP peaks between 500ms and 800ms over occipital-parietal regions and is thought to reflect attentional control towards the location of an anticipated target stimulus on a supra-modal level, as this component has also been found in experiments using auditory spatial attention tasks (Di Russo et al., 2021; Eimer et al., 2003; Van der Lubbe & Utzerath, 2013). The LDAP also reflects preparatory activity for the upcoming target stimulus and the marking of the attended location in which it is expected to appear, increasing the target stimulus' processing and enhancing the to-be-given response (Hopf & Mangun, 2000).

Although the three ERL components have been investigated by numerous studies (e.g., De Russo et al., 2021; Lassalle & Itier, 2013; Marika, Valentina, Livio, Sabrina, & Mussini, 2020), the effect of mental fatigue or ToT on them received less attention and, to the best of the authors knowledge, has not been analyzed yet. However, since attention has been shown to decrease with increasing ToT and mental fatigue (Martel et al., 2014; Wascher et al., 2016; Wascher, Rasch, et al., 2014), the same can be expected of visuospatial attention. Therefore, with increasing ToT, a decrease in the EDAN, ADAN, and LDAP components amplitude can be hypothesized.

1.3.4 The P3b component

The P3b is a positive ERP component peaking around 500ms post-stimulus over parietal regions (Möckel et al., 2015; Verleger, 2020). The use of the P3b as a neurophysiological marker for certain cognitive processes has been of considerable interest, however, its interpretation has also led to controversy and disagreement in previous literature (see Verleger, 2020 for a detailed review). However, the P3b amplitude has been commonly associated with the amount of attentional resources involved in stimulus processing based on a task relevance evaluation (Polich, 2007). Also, the component is associated with higher-order processes of cognitive control such as, for instance, reasoning and problem-solving (Motes et al., 2014; Polich, 1996, 1998). During prolonged execution of highly routinized and mundane tasks, ToT was found to significantly modulate the P3b by reducing its amplitude which is associated with attentional lapses (O'Connell et al., 2009). In line with these findings, a reduction in the P3b amplitude was also found to correlate with increased mind-wandering (Smallwood, Beach, Schooler, & Handy, 2008).

1.3.5 The effect of final spurt phenomena on ERP components

The ACC has been shown to be significantly affected by elevated levels of motivation, which was associated with more efficient top-down attention (re-)orientation (Pessoa, 2009). Therefore, an increasing amplitude in the P2, N2 as well as ADAN ERP/ERL component can be expected when motivation in individuals increases. In line with this hypothesis, research has found increasing N2 amplitudes in fatigued subjects who have been motivated to further engage in a prolonged task, reflecting increased cognitive control (Boksem et al., 2012; Boksem et al., 2006; Lorist et al., 2005). Also, Wascher et al. (2014) reported that the N2 is related to the frontal midline theta frequency band, which in turn reliably reflects changes in cognitive processes related to mental fatigue. In addition, the difference in the N2 amplitude between repetition and switch trials can be expected to emerge again after successfully motivating an individual (Boksem et al., 2005; Lorist et al., 2000). For the ADAN, however, the effect of motivation has not been studied yet but has to be tested.

Regarding parietal brain regions, previous research on the effects of prolonged task performance has revealed that increased levels of motivation counteracting mental fatigue in individuals have a significant positive effect on the P3b amplitude (Boksem et al., 2006). Despite the controversies in its interpretation, the increased P3b could presumably reflect increased stimulus processing based on increased attention allocation (Motes et al., 2014; Polich, 2007). Also, increased power in the EDAN and LDAP lateralization can be expected to occur with increased motivation to further engage in a certain task. Although they have neither been investigated yet within the context of ToT nor final spurt phenomena, reduced error rates and response times indicate elevated levels of attentional orienting and trace of the expected target stimulus which both are reflected in the EDAN and LDAP lateralization, respectively (Di Russo et al., 2021; Hopf & Mangun, 2000; Velzen & Eimer, 2003).

1.4 The aim of this study

In order to further clarify the effect of motivation on mental fatigue and task performance during prolonged task execution, the current study aimed at analyzing both mental fatigue, measured in terms of performance decrement, and final spurt effects in one paradigm. More specifically, this study aimed at verifying the use of time-related information in the form of a progress bar to decrease mental fatigue and to elicit a final spurt phenomenon in individuals. It investigated whether the expected proximate termination of a prolonged task indicated by an almost completely filled progress bar increases motivation (Thönes et al., 2018). To analyze ToT effects and the effectiveness of the progress bar, self-reported and behavioral measures as well as ERP/ERL correlates were compared between a condition providing participants with time-related information and a condition without this information.

Mental fatigue was induced by prolonged task performance. In order to investigate the effect of ToT and final spurt phenomena on cognitive processes as top-down driven attention allocation, including visuospatial attention, a combined Posner cueing-task switching paradigm was chosen. The Posner cueing paradigm is a standard way of examining visuospatial attention based on endogenous orienting using a centrally displayed cue, as for instance an arrow (Posner, 1980). The chosen Posner cueing-task switching paradigm additionally enabled the assessment of changes in endogenous information encoding processes from the working memory, since the task requirements were presented only in the beginning and not during the task performance. As explained above, the cognitive process of visuospatial attention allocation and of information encoding is expected to be specifically reflected in the chosen ERL components and the P2 ERP component, respectively (Di Russo et al., 2021; Hopf & Mangun, 2000; Lenartowicz et al., 2010). The research question of this study is whether *ToT effects are modulated by feedback about the foreseeable termination of a prolonged task.* If so, this effect is expected to occur in form of a reduced or counteracted ToT effect towards the end of experimental blocks in which a progress bar is presented compared to blocks in which a progress bar is not presented. The effect is expected to be reflected in self-reported, behavioral, and electrophysiological measures.

2 Method

2.1 Participants

Since two participants reported to pay very little attention to the progress bar, they were excluded from the sample, leaving a total of 30 participants (M_{age} = 24.73 years, SD_{age} = 4.11; 15 female and 15 men). All subjects were between 18 and 35 years old and neurologically, psychiatrically, as well as physically healthy. Further criteria included having normal or corrected to normal vision, being right-handed, as well as not suffering from sleep deprivation. All subjects were provided with information about the experiment and signed an informed consent (see Appendix I and II). Their handedness was assessed using the *Edinburgh Handedness Inventory* (see Appendix III). The acquisition of participants was conducted via the Facebook network of the research institute and based on a register of former participants. Participants' anonymity was assured and they participated voluntarily. The study was approved by the ethics committee of the Leibniz Research Centre for Working Environment and Human Factors Dortmund and was in accordance with the declaration of Helsinki.

2.2 Procedure and stimuli

All participants were instructed to arrive at the laboratory at 9:00 a.m. to minimize differences in circadian effects. Subjects were not informed about the duration of the experiment and were asked to leave their mobile phones and watches outside the EEG room in order to avoid that they had information about the progressing time during the experiment. After the EEG cap was prepared, participants were tested. The EEG room was dimly lit, sound attenuated, and electrically shielded. For the presentation of instructions and visual stimuli, a 22-in CRT monitor (refresh rate: 100Hz) was positioned in front of the participants at a distance of 1.40m. Before the experiment started, participants were presented with explanations about the tasks to be solved. Also, they were informed that during the experimental blocks, a bar was presented which either appears as a progress bar indicating the progress of the experimental block, or in form of a static bar, thus, not indicating the progress of the experimental block.

The experiment consisted of two main tasks, namely a number response task (NRT) and a picture rating task (PRT) which were both repeated eight times. Hereby, each block of the number response task was followed by a block of the picture rating task, which in turn was followed by a short self-estimated break of a few seconds (see Figure 1).

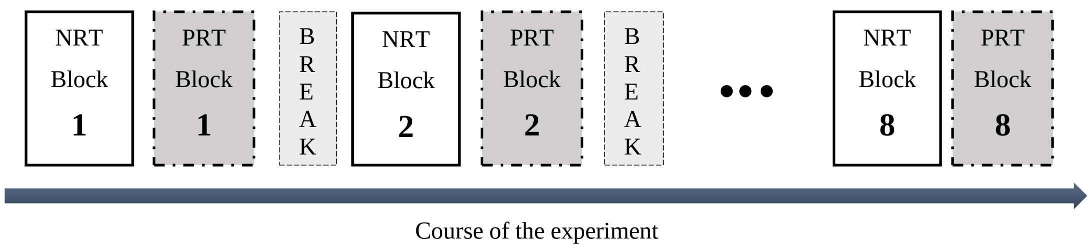

Figure 1. A schematic overview of the sequence of blocks from the number response task (NRT) and picture rating task (PRT) over the course of the experiment. Each NRT block was followed by a PRT block, which in turn was followed by a short self-estimated break of a few seconds.

The number response task, which is more detailed explained in section *2.3 Task*, consisted of a combined Posner cueing-task switching paradigm. At first, a fixation cross was presented in the middle of the screen, surrounded by two empty boxes on the left and right side as well as a progress/static bar above and below (see Figure 2). After 1000ms, the fixation cross was replaced by a task cue in form of either a circle or diamond (presentation duration: 200ms, mean inter-trial interval: 3200ms). Following an 600ms inter-stimulus interval during which the fixation cross was presented again, the spatial cue in form of an arrow pointing either left or right was displayed (presentation duration: 200ms), cueing the side of the appearance of the target stimulus with 80% validity. After another inter-stimulus interval of 600ms presenting the fixation cross, the target stimulus in form of a number between 1 and 9 (leaving out the 5) was displayed either in the left or right box with a filler stimulus in the other box (three horizontal lines, similar to the number in size and luminance) to which participants then responded. The experiment consisted of four blocks varying in their duration from 80 to 120, 160, and 200 trials. Each block duration occurred twice during the experiment, one time with a progress bar and one time without a progress bar, thus, with a static grey bar, resulting in eight blocks in total. The order of the block duration was random, however, switching between blocks presenting and not presenting a progress bar on every subsequent block. When the progress bar was presented, it was filled proportionally from the inside to the outside of the bar with the progress of the experimental block (see Figure 2).

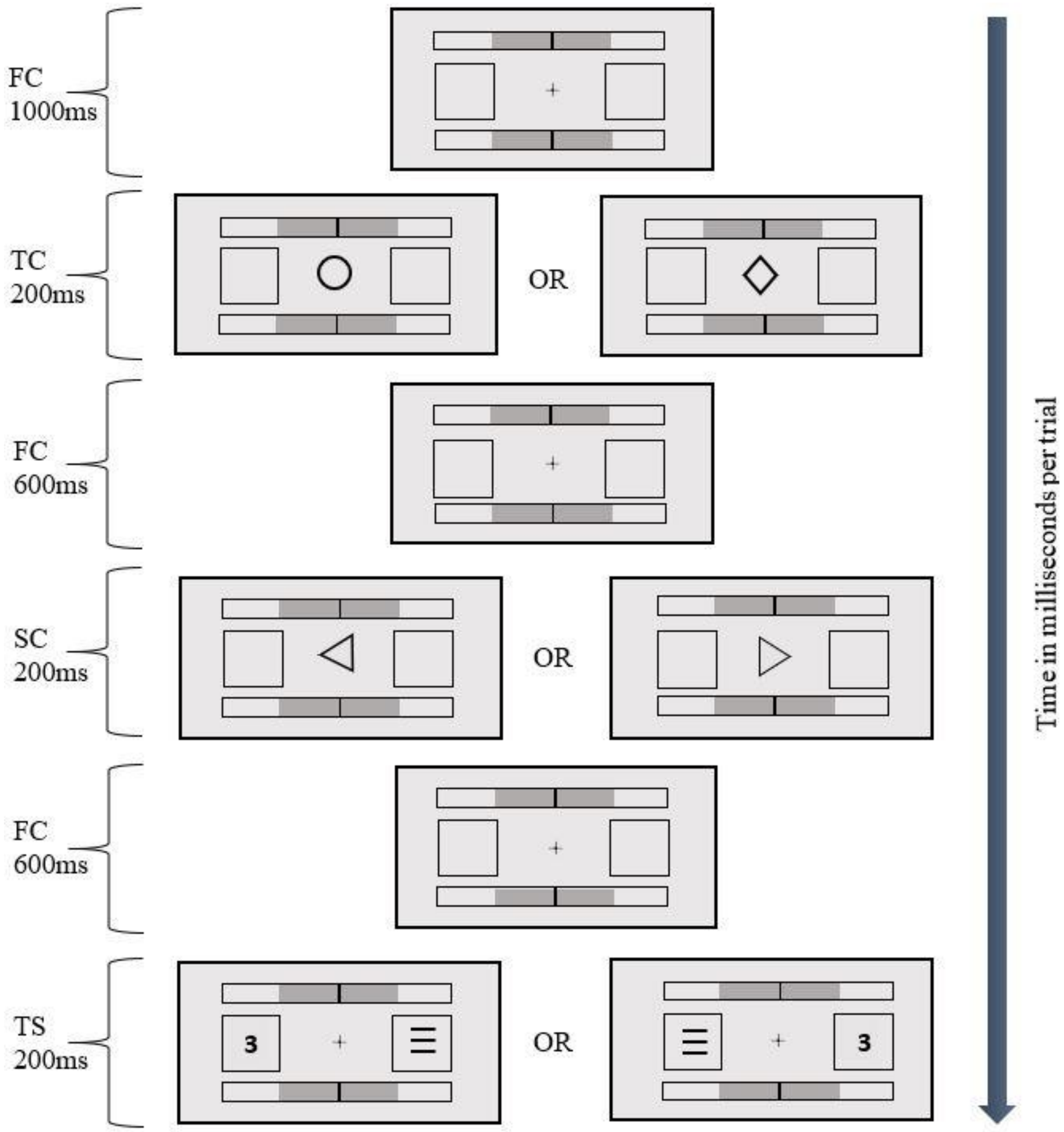

Figure 2. An example of the stimulus sequence in a trial for the number response task using a combined Posner cueing-task switching paradigm. The progress bar is located above and below the stimuli and is already half-filled in this example. A fixation cross (FC) was presented which was then replaced by the task cue (TC; circle or diamond), determining the to-be-solved task. Depending on the shape, participants had to either decide if the target stimulus presented later on is larger/smaller than 5, or odd/even. After switching back to the FC, the spatial cue (SC) was presented indicating the side on which the target stimulus would appear with 80% validity. After switching back to the FC, the target stimulus (TS; in this example the number 3) and a filler stimulus on the other side were presented, to which the participant had to respond to, depending on the presented TC.

In order to create a positive feeling in participants about the approaching end of a trial block, the picture rating task was integrated into the experiment. After each block of the number response task, participants were presented with 13 pictures one after another, randomly selected from a set of 203 pictures in total. The pictures were retrieved from the Emotional Picture Set (EmoPicS, Wessa et al., 2010) and neutrally affective (+/- 1 *SD* around the mean value of arousal and valency of the whole set). The neutrality of pictures should ensure to not actively bias participants affectively and thus create a confounding variable, but at the same time to provide participants with variety and a welcoming change of the task set after each experimental block to which they could look forward to. After each response, the next picture was presented until participants had responded to all 13 pictures. In total, the experiment including both tasks lasted on average 116 minutes (*SD* = 4.2).

2.3 Task

In the number response task, participants had to respond by pressing one of two keys depending on the task cue and target stimulus appearance. The two shapes of the task cue were associated with two kind of instructions, depending on the condition the participant was assigned to: either for the circle it had to be decided if the subsequent target stimulus was a number above or below 5, and for the diamond it had to be decided if the target stimulus was an odd or even number, or the other way around. The assignment of the conditions was counterbalanced between participants.

For the picture rating task, participants had to indicate how much they liked each of the 13 pictures presented, using a keyboard ranging from 1 (*not at all*) to 9 (*a lot*).

2.4 Self-reported measures

After the 8 task-blocks were finished, subjects filled out a follow-up questionnaire and rated the perceived effort to work on the number-response task and its perceived demand using a visual analogue scale (see Appendix IV). Hereby, the left side of the scale represented low levels of the respective experience, whereas the right side of the scale represented high levels of the experience. Also, participants reported how much they attended the displayed progress bar, as well as their perceived level of motivation, mind wandering, and how much they felt being mentally absorbed in the task when a progress bar and when a static bar were presented. Although a repeated measure of these self-reported variables during the experiment could have provided a more detailed insight regarding potential changes over time, it was decided to not do so. Encouraging participants to engage in introspection during the task execution could have turned into a confounding variable as it could have distracted participants from the task and increase task withdrawal.

2.5 Behavioral analysis

Behavioral measures included the response time and response accuracy. Responses were categorized as correct if the right key button was pressed between 150ms and 1500ms post-target stimulus. Responses not meeting these criteria were categorized as wrong.

2.6 EEG data recording

The EEG was recorded using an electrode-cap with 64 active Ag/AgCl electrodes (ActiCap; BrainProducts, Gilching, Germany) arranged based on the 10-10 system (Pivik et al., 1993). Electrodes were grounded to electrode AFz and FCz served as an online-reference during recording. Electrode impedances were kept below 10 kΩ and EEG-signals were amplified using the Bittium NeurOne Tesla (Bittium, Oulu, Finland; sampling rate: 1000Hz, sampling interval: 2000ms).

2.7 EEG data preprocessing

The preprocessing of EEG data was conducted using the MATLAB R2020a (The Math Works) toolbox *EEGLab* (Delorme & Makeig, 2004). At first, data were re-referenced to the common average reference across all electrodes and a bandpass filter of 0.5 and 20Hz was applied. Detection of bad channels was conducted using kurtosis and probability criteria, resulting in the removal of 3.63 (*SD* = 2.50) channels on average, which were then interpolated. Next, epoch-segmentation was applied time-locked from 400ms pre- to 2800ms post-task cue. Epochs containing artefacts were identified and removed automatically. On average, 240,01 (*SD* = 71.54) trials were rejected. Subsequently, an independent component analysis (ICA) was calculated on the remaining data and ICLabel (Pion-Tonachini, Kreutz-Delgado, & Makeig, 2019) was used to identify independent components (ICs) reflecting artefacts including eye-movements, which were then removed. This resulted in the removal of 29.53 (*SD* = 6.20) IC's on average. Finally, the data were baseline-corrected using the 200ms preceding the task cue.

2.8 ERP and ERL analysis

For the ERP analysis at both, frontal and parietal recording sites, 20 Hz low-pass filtered data were used. For frontal sites, these were averaged across the electrodes Fz, F1, F2, and FCz. In order to determine the time windows for calculating the mean amplitude for each ERP component, the most positive/negative deflections of the signal in the grand average, thus, averaged across subjects and conditions, were identified. For the positive deflection of the P2, a time window in the range from 100ms to 300ms after the onset of the task cue and the target stimulus was identified. The P2 was then parameterized as the mean amplitude in a 30ms wide time window centered at the identified peak from the grand average. For the N2 component the same procedure was applied, with the difference of identifying the most negative deflections in the time windows of 200 to 400ms after the task cue and the target stimulus. Parietal ERPs were averaged across the electrodes Pz, P1, and P2. For parameterizing the P3b, a fixed time window was used, ranging from 450 to 550ms relative to the onset of the task cue and target stimulus.

For the EDAN and LDAP component, the ERL was calculated as the contralateral minus ipsilateral activation at the electrode pairs PO3/PO4 and PO7/PO8 with respect to the direction of the spatial cue. The same was calculated for the ADAN component across the electrode pairs F3/F4, FC1/FC2, and FC3/FC4. Then, the EDAN, ADAN, and LDAP were calculated as the mean in a 20ms wide time window centered at the maximum positive/negative lateralization in the averaged signal, across subjects and conditions, in the latency range of 150ms to 350ms, 350ms to 500ms, and 500ms to 800ms, respectively, relative to the spatial cue.

2.9 Statistical analysis

The statistical analysis was also conducted in MATLAB R2020a (The Math Works). In order to analyze the effects of the progress bar on the self-reported ratings of perceived motivation, mind wandering, and feelings of being mentally absorbed in the task (i.e., task engagement), participants' responses were measured based on their location on the analogue scale and subsequently classified on a 10-point scale. Afterwards, pairwise *t*-tests as well as effect sizes of Cohen's *d* were calculated.

The objective of this study was to investigate the influence of a progress bar on the task performance and mental fatigue of individuals as a potential modulation of ToT effects. Therefore, ToT was defined by comparing the first and last 25% of the trials within each experimental block (i.e., begin vs. end). Although previous studies have also often accounted for within-block changes of behavioral or EEG data by dividing experimental blocks into sub-blocks (see e.g., Arnau et al., 2017; Möckel et al., 2015), it was decided to not do so in this current research. The reason for this decision was the significantly shorter duration of the experimental blocks. In previous studies, the blocks lasted around 70 minutes, divided into sub-blocks of around 20 minutes each which served as the basis for measures of within-block changes (e.g., Möckel et al., 2015). In contrast, the blocks duration in the current study varied between 4.27 to 10.67 minutes (*M* = 7.47 minutes), thus, significantly shorter. This duration was therefore not expected to cover significant within-block changes of the chosen factors.

To test for effects of ToT, trial sequence (SEQ; i.e., repetition vs. switch trials), and the (progress) bar (BAR; i.e., static vs. progress), generalized linear mixed effect models (GLME) and linear mixed effect models (LME) were fitted to the behavioral as well as the ERP data, respectively. As the dependent variables, the response time and response accuracy were set in the GLME, and the averaged amplitude peaks of the P2, N2, P3b, as well as EDAN, ADAN, and LDAP were set in the LME. As fixed effects, the factors ToT, SEQ and BAR were set, using the participants as the grouping variable. To account for inter-individual differences, a random intercept with a fixed slope was modeled for each participant, leading to the formula "dependent variable ~ ToT * SEQ * BAR + (1|participant)" for both the GLME and LME. To account for potential type I errors, the bias-corrected partial eta squared, subsequently referred to as η_p^2, was calculated for all estimations of effect size (Mordkoff, 2019). Regarding its classification as being small, medium, or large, the conventions of Cohen (1992) were used. For the pairwise t-tests as well as the GLME and LMEs, a significance level of .05 was chosen.

3 Results

3.1 Self-reported measures

Self-reported measures for the perceived task demand and effort to work on the number-response task revealed average ratings of 4.57 (*SD* = 2.92) and 6.12 (*SD* = 2.23), respectively, on the 10-point scale. Also, an average rating of 8.28 (*SD* = 1.19) was revealed in respect to how much attention was spent towards the progress bar during the experiment. Participants felt significantly more motivated and engaged in the number-response task for blocks in which a progress bar was displayed to them (*M* = 7.33, *SD* = 1.92; *M* = 6.60, *SD* = 1.63, respectively) compared to blocks in which a static bar was presented (*M* = 3.42, *SD* = 2.17; *M* = 4.89, *SD* = 2.11, respectively), as the significant effects for the factor BAR indicates ($t(29) = 7.63$, $p <.001$, $d = 1.38$ and $t(29) = 3.99$, $p <.001$, $d = .83$, respectively). In addition, mind wandering was also reported being significantly lower for blocks presenting a progress bar (*M* = 4.22, *SD* = 2.18) compared to blocks presenting a static bar (*M* = 5.93, *SD* = 1.97; $t(29) = -5.40$, $p <.001$, $d = -.77$).

3.2 Behavioral measures

For the purpose of clarity, only significant effects of the behavioral and ERP analysis are reported. However, an overview of the whole statistical analysis including corresponding test statistics of the behavioral data can be found in Table 1. Regarding response times, the analysis revealed significant main effects for the factors ToT ($\beta = 24.33$, $p = <.05$, $\eta_p^{2} = .12$) and trial sequence SEQ ($\beta = 56.27$, $p = <.001$, $\eta_p^{2} = .46$), as well as a significant interaction effect between both factors ($\beta = -44.58$, $p = <.01$, $\eta_p^{2} = .20$). More specifically, for the ToT main effect, response times significantly increased with increasing ToT (M_{begin} = 736ms, SD_{begin} = 146ms and M_{end} = 743ms, SD_{end} = 155ms). For the SEQ main effect, response times for repeat trials were significantly faster than for switch trials ($M_{\text{repetition}}$ = 725ms, $SD_{\text{repetition}}$ = 150ms and M_{switch} = 754ms, SD_{switch} = 149ms). Regarding the interaction between ToT and SEQ, it can be seen in Figure 3 that response times for repeat trials increased with ToT ($M_{\text{repetition\_begin}}$ = 712ms, $SD_{\text{repetition\_begin}}$ = 143ms, and $M_{\text{repetition\_end}}$ = 738ms, $SD_{\text{repetition\_end}}$ = 157ms), whereas response times for switch trials decreased ($M_{\text{switch\_begin}}$ = 760ms, $SD_{\text{switch\_begin}}$ = 145ms, and $M_{\text{switch\_end}}$ = 749ms, $SD_{\text{switch\_end}}$ = 153ms).

Regarding the accuracy, the analysis revealed a significant SEQ main effect ($\beta = -.03$, $p = <.01$, $\eta_p^{2} = .17$). The accuracy scores in repetition trials were significantly higher than in switch trials ($M_{\text{repetition}}$ = .88, $SD_{\text{repetition}}$ = .10, and M_{switch} = .85, SD_{switch} = . 11).

Table 1

For response time and accuracy, this table shows the test statistics (t), corresponding effect sizes (adjusted partial eta squared; η_p^2), regression coefficients (ß), as well as the 95% confidence interval (CI) for the fixed effects Time on Task (ToT, that is begin vs. end), trial sequence (SEQ, that is repetition vs. switch), progress bar (BAR, that is static vs. progress), and their interaction

	Response times				Accuracy			
Factor	t	η_p^2	β	95% CI	t	η_p^2	β	95% CI
ToT	2.23 *	.12	24.33	2.79, 45.86	-.54	-.02	-.01	-.03, .02
SEQ	5.15 ***	.46	56.27	34.74, 77.80	-2.64 **	.17	-.03	-.06, -.01
BAR	0.79	-.01	8.72	-13.01, 30.45	1.13	.01	.01	-.01, .04
ToT x SEQ	-2.88 **	.20	-44.58	-75.03, -14.13	.23	-.03	.00	-.03, .04
ToT x BAR	-0.23	-.03	-3.64	-34.37, 27.09	-1.73	.06	-.03	-.07, .00
SEQ x BAR	-1.10	.01	-17.02	-47.61, 13.56	-.27	-.03	-.00	-.04, .03
ToT x SEQ x BAR	1.02	.00	22.42	-20.84, 65.68	.81	-.01	.02	-.03, .07

Note . *p < .05. **p < .01. ***p < .001

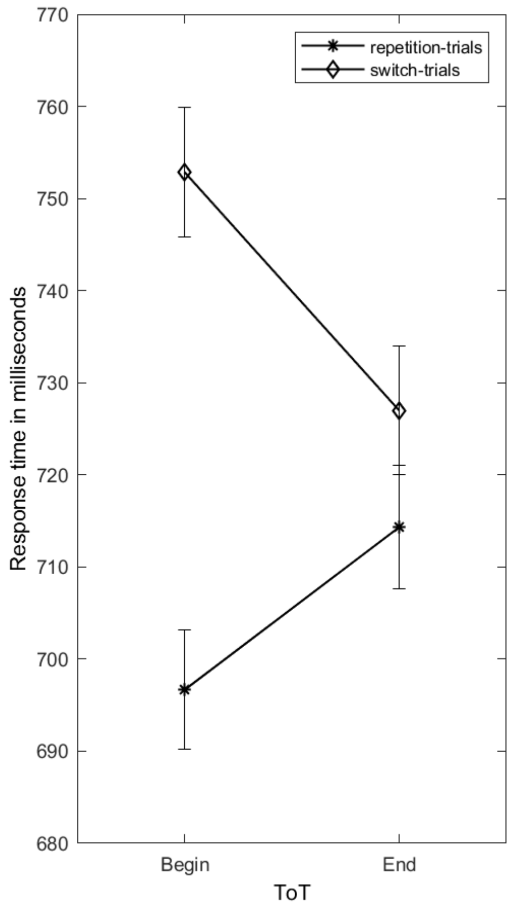

Figure 3. Mean response times for the interaction effect between the fixed factors trial sequence (SEQ, that is repetition vs. switch) and Time on Task (ToT, that is begin vs. end). The error bars are representing the standard error.

3.3 ERPs

For the P2 component, main effects elicited by the task cue for the factors ToT (β = -.43, p = <.05, $\eta_p{}^2$ = .10) and SEQ (β = -.43, p = <.05, $\eta_p{}^2$ = .09) were identified (see Table 2). More specifically, the P2 amplitude significantly decreased with increasing ToT (M_{begin} = 1.1µV, SD_{begin} = 1.7µV and M_{end} = .9µV, SD_{end} = 1.3µV). For SEQ, the P2 amplitude was significantly decreased for switch trials compared to repetition trials (M_{switch} = .9µV, SD_{switch} = 1.4µV, and $M_{repetition}$ = 1.1µV, $SD_{repetition}$ = 1.5µV). Both main effects can be seen in Figure 4.

Table 2

For the ERP component P2, this table shows the test statistics (t), corresponding effect sizes (adjusted partial eta squared; $\eta_p{}^2$), regression coefficients (ß), as well as the 95% confidence interval (CI) for the fixed effects Time on Task (ToT, that is begin vs. end), trial sequence (SEQ, that is repetition vs. switch), progress bar (BAR, that is static vs. progress), and their interaction for both effects elicited by the task cue and target stimulus

	P2 task cue				P2 target stimulus			
Factor	t	$\eta_p{}^2$	β	95% CI	t	$\eta_p{}^2$	β	95% CI
ToT	-2.05 *	.10	-.43	-.85, -.02	-.44	-.03	-.10	-.52, .33
SEQ	-2.01 *	.09	-.43	-.84, -.01	.36	-.03	.08	-.35, .50
BAR	-.85	-.01	-.18	-.60, .24	.62	-.02	.13	-.29, .56
ToT x SEQ	.36	.03	.11	-.48, .70	-.73	-.02	-.22	-.83, .38
ToT x BAR	1.24	.02	.37	-.22, .96	-.12	-.03	-.04	-.64, .57
SEQ x BAR	1.47	.04	.44	-.15, 1.03	-1.29	.02	-.40	-1.00, .21
ToT x SEQ x BAR	-.53	-.02	-.22	-1.06, .61	.79	-.01	.34	-.51, 1.20

Note. *p < .05. **p < .01

For the N2 component, a significant main effect elicited by the task cue for the factor SEQ (β = -.54, p = <.01, $\eta_p{}^2$ = .14) was identified. The N2 amplitude significantly decreased for repetition trials compared to switch trials ($M_{repetition}$ = -2.8µV, $SD_{repetition}$ = 1.6µV, and M_{switch} = -3.0µV, SD_{switch} = 1.6µV; see Table 3 and Figure 4).

Table 3

For the ERP component N2, this table shows the test statistics (t), corresponding effect sizes (adjusted partial eta squared; $\eta_p{}^2$), regression coefficients (ß), as well as the 95% confidence interval (CI) for the fixed effects Time on Task (ToT, that is begin vs. end), trial sequence (SEQ, that is repetition vs. switch), progress bar (BAR, that is static vs. progress), and their interaction for both effects elicited by the task cue and target stimulus

	N2 task cue				N2 target stimulus			
Factor	t	$\eta_p{}^2$	β	95% CI	t	$\eta_p{}^2$	β	95% CI
ToT	.59	-.02	.13	-.31, .56	.83	-.01	.20	-.28, .67
SEQ	-2.46 **	.14	-.54	-.98, -.11	.75	-.01	.18	-.29, .66
BAR	-1.53	.04	-.34	-.77, .10	1.36	.03	.33	-.15, .80
ToT x SEQ	.27	-.03	.08	-.53, .70	-.91	-.01	.-.31	-.98, .36
ToT x BAR	-.22	-.03	-.07	-.68, .55	-1.31	.02	-.45	-1.12, .22
SEQ x BAR	1.91	.08	.60	-.02, 1.21	-.98	-.00	-.33	-1.00, .34
ToT x SEQ x BAR	.07	-.03	.03	-.84, .90	.44	-.03	.21	-.74, 1.16

Note. *p < .05. **p < .01

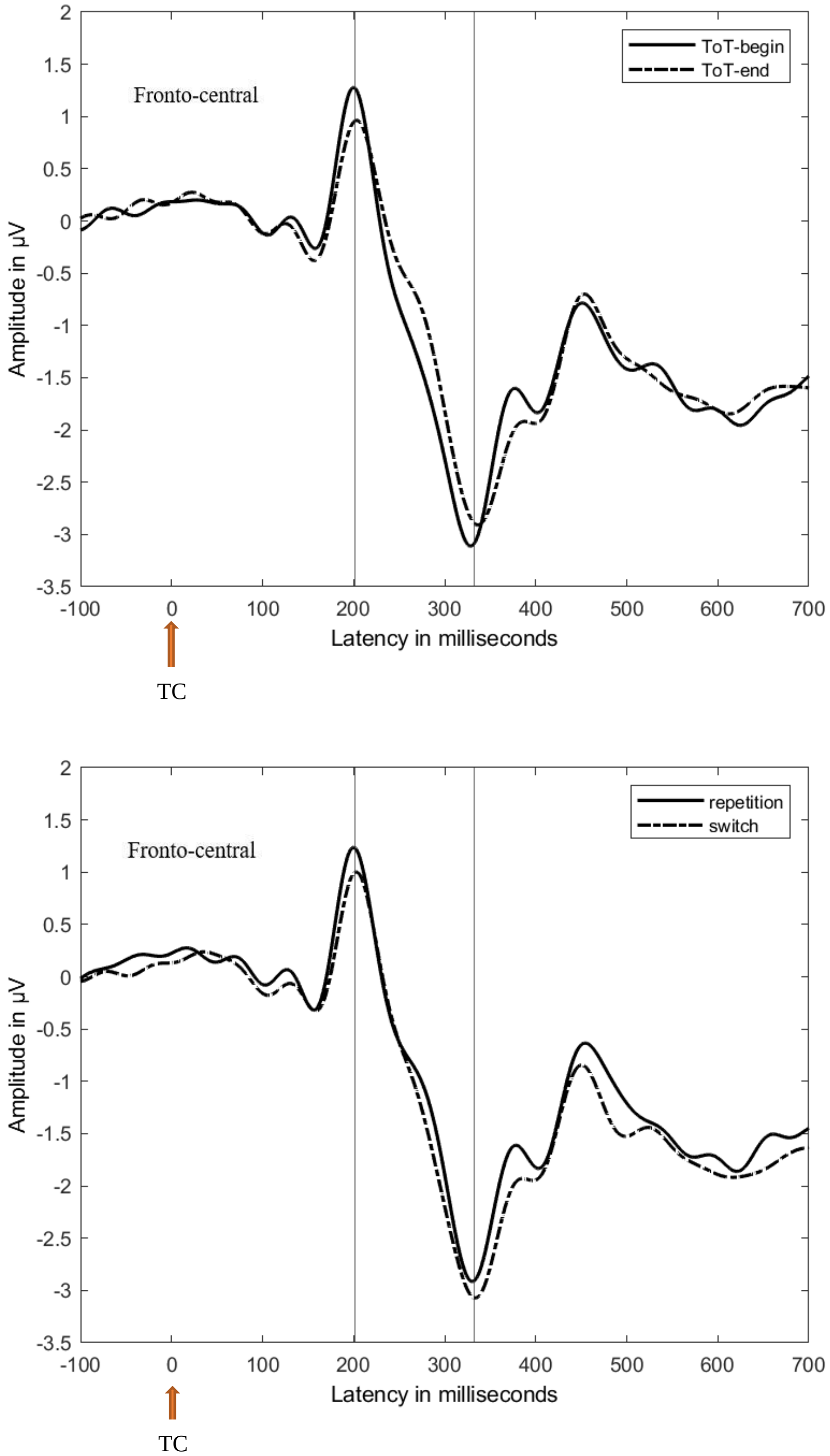

Figure 4. The P2 and N2 amplitudes superimposed across electrodes Fz, F1, F2 and FCz for the main effects of Time on Task (ToT, that is begin vs. end; above) and trial sequence (SEQ, that is repetition vs. switch; below). Hereby, 0ms refers to the task cue (TC) onset.

For the lateralizations, only for the ADAN component significant main and interaction effects were identified (see Table 4). A main effect for ToT (β = .42, p = <.05, $\eta_p{}^2$ = .13) was found, as the amplitude significantly decreased with increasing ToT (M_{begin} = -.2μV, SD_{begin} = .7μV and M_{end} = -.0μV, SD_{end} = .7μV; see Figure 5). In addition, a significant interaction effect for ToT and BAR (β = -.61, p = <.05, $\eta_p{}^2$ = .14) was revealed. The ADAN amplitude decreased significantly stronger with increasing ToT when a static bar was presented (M_{begin_static} = -.3μV, SD_{begin_static} = .6μV and M_{end_static} = .1μV, SD_{end_static} = .6μV), as when a progress bar was presented ($M_{begin\_progress}$ = -.2μV, $SD_{begin\_progress}$ = .7μV and $M_{end\_progress}$ = -.2μV, $SD_{end\_progress}$ = .7μV), as can be seen in Figure 6. A topography of the EDAN and LDAP component can be seen in Figure 7.

Table 4

For the ERL components ADAN, EDAN and LDAP, this table shows the test statistics (t), corresponding effect sizes (adjusted partial eta squared; $\eta_p{}^2$), regression coefficients (ß), as well as the 95% confidence interval (CI) for the fixed effects Time on Task (ToT, that is begin vs. end), trial sequence (SEQ, that is repetition vs. switch), progress bar (BAR, that is static vs. progress), and their interaction for effects elicited by the task cue and target stimulus

	EDAN spatial cue				ADAN spatial cue				LDAP spatial cue			
Factor	t	η_p^2	β	95% CI	t	η_p^2	β	95% CI	t	η_p^2	β	95% CI
ToT	1.23	.02	.29	-.18, .76	2.36 *	.13	.42	.07, .76	-.37	-.03	-.08	-.52, .35
SEQ	-.06	-.03	-.01	-.48, .45	-1.05	.00	-.19	-.53, .16	-.22	-.03	-.05	-.49 .39
BAR	.55	-.02	.13	-.34, .60	.29	-.03	.05	-.30, .40	.34	-.03	.07	-.36, .51
ToT x SEQ	-1.01	.00	-.34	-1.00, .32	-.42	-.03	-.10	-.60, .39	-.17	-.03	-.05	-.67, .56
ToT x BAR	0.43	-.03	-.14	-.81, .52	-2.44 *	.14	-.61	-1.10, -.12	-.38	-.03	-.12	-.74, .50
SEQ x BAR	-.00	-.03	-.00	-.66, .66	.28	-.03	.07	-.42, .56	.37	-.03	.12	-.50, .74
ToT x SEQ x BAR	1.01	.00	.48	-.46, 1.42	1.44	.03	.51	-.19, 1.20	.50	-.03	.22	-.65, 1.10

Note. *p < .05. **p < .01

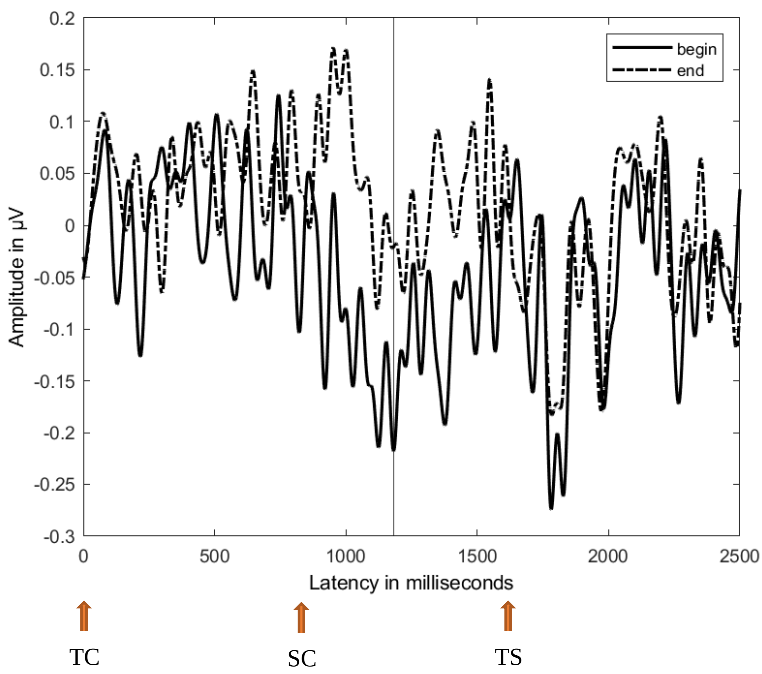

Figure 5. The grand average topography of the contra-ipsilateral ERP difference calculated at the electrode pairs F3/4, FC1/2 and FC3/4. Hereby, 0ms refers to the task cue (TC) onset, 800ms refers to the spatial cue (SC) onset, and 1600ms refers to the target stimulus (TS) onset. The xline marks the ADAN component.

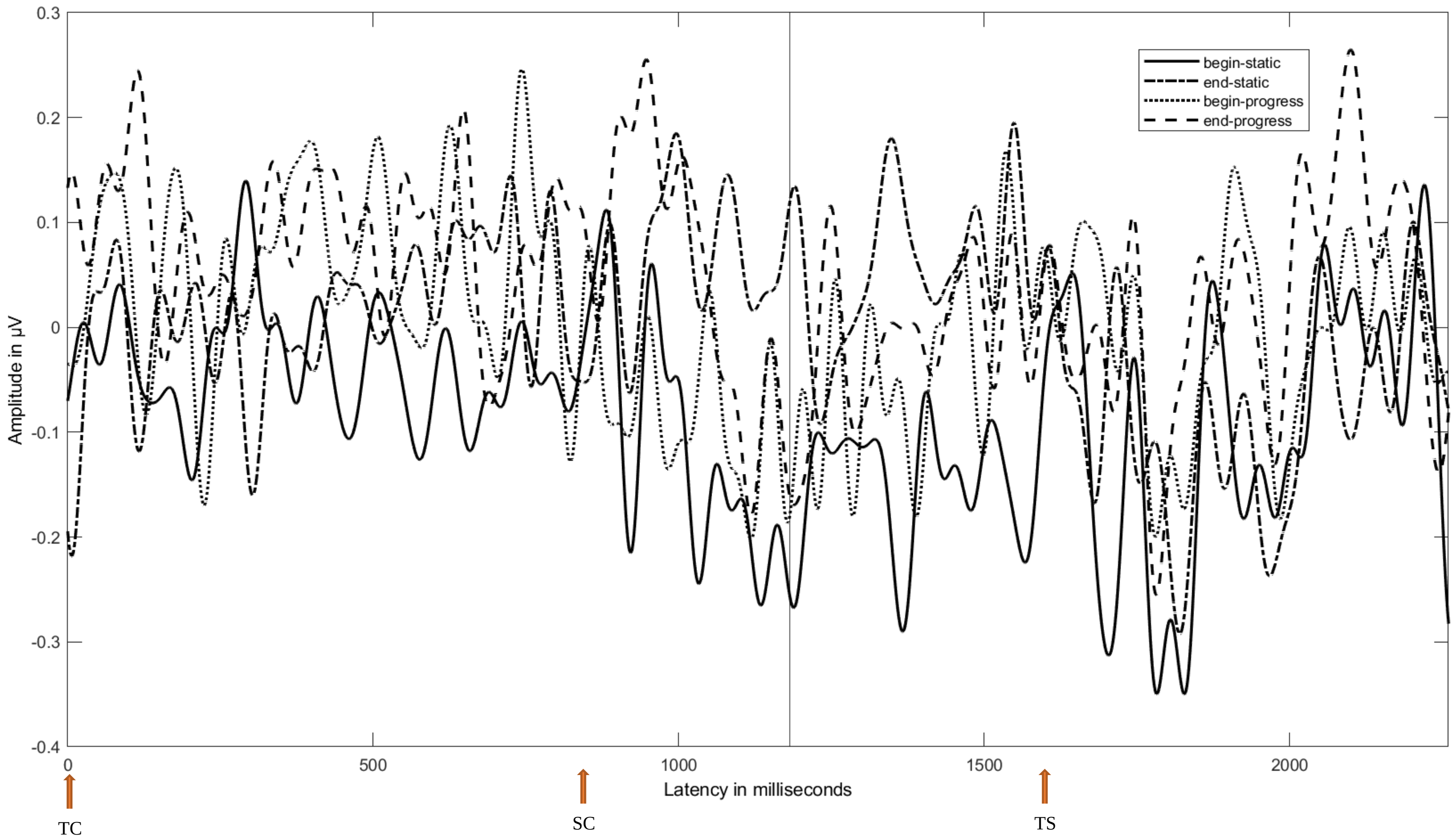

Figure 6. The grand average topography of the contra-ipsilateral ERP difference calculated at the electrode pairs F3/4, FC1/2 and FC3/4 for the interaction effect of ToT (i.e., begin vs. end) and BAR (i.e., static vs. progress). Hereby, 0ms refers to the task cue (TC) onset, 800ms refers to the spatial cue (SC) onset, and 1600ms refers to the target stimulus (TS) onset. The xline marks the ADAN component.

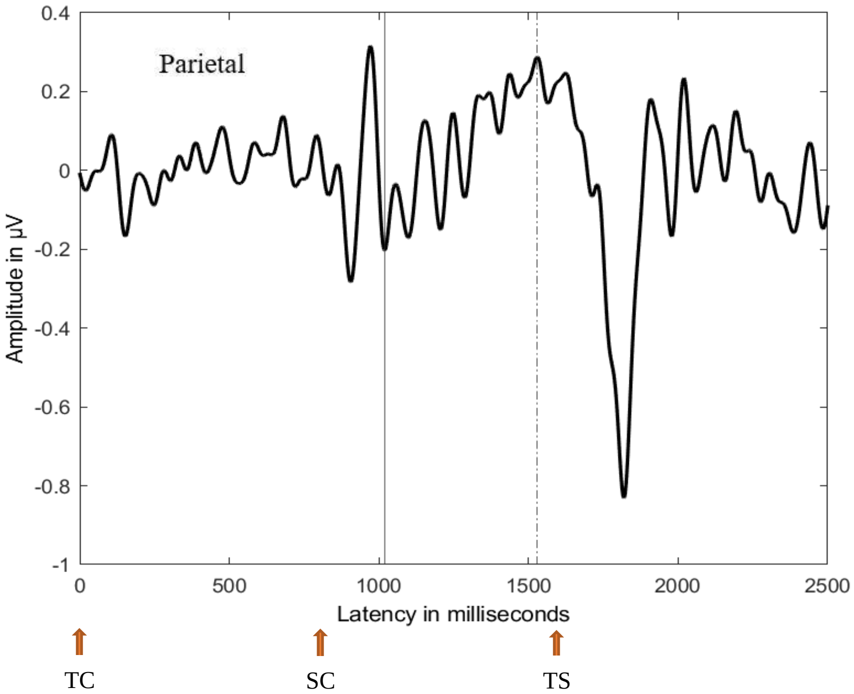

Figure 7. The grand average topography of the contra-ipsilateral ERP difference calculated at the electrode pairs PO3/4 and PO7/8. The xlines at 1020ms (straight line) and 1530ms (dotted line) mark the EDAN and LDAP lateralization, respectively. Hereby, 0ms refers to the task cue onset (TC), 800ms refers to the spatial cue onset (SC), and 1600ms refers to the target stimulus onset (TS).

Lastly, for the P3b component, a significant main effect elicited by the target stimulus for the factor ToT (β = .37, p = <.05, $\eta_p{}^2$ = .12) was found. More specifically, the P3b amplitude significantly increased with increasing ToT (M_{begin} = 3.3µV, SD_{begin} = 1.6µV, and M_{end} = 3.5µV, SD_{end} = 1.6µV), as can be seen in Table 5 and Figure 8.

Table 5

For the ERP component P3b, this table shows the test statistics (t), corresponding effect sizes (adjusted partial eta squared; $\eta_p{}^2$), regression coefficients (ß), as well as the 95% confidence interval (CI) for the fixed effects Time on Task (ToT, that is begin vs. end), trial sequence (SEQ, that is repetition vs. switch), progress bar (BAR, that is static vs. progress), and their interaction for effects elicited by the task cue, target stimulus, and spatial cue

	P3b task cue				P3b target stimulus			
Factor	t	$\eta_p{}^2$	β	95% CI	t	$\eta_p{}^2$	β	95% CI
ToT	-.94	.00	-.17	-.53, .19	2.21 *	.12	.37	.04, .70
SEQ	.19	-.03	.03	-.32, .39	-.62	-.02	-.10	-.43, .23
BAR	.07	-.03	.01	-.34, .37	.08	-.03	.01	-.32, .35
ToT x SEQ	.74	-.02	.19	-.32, .69	-1.22	.02	-.29	-.76, .18
ToT x BAR	.94	.00	.24	-.26, .74	-.27	-.03	-.06	-.53, .40
SEQ x BAR	.99	.00	.25	-.25, .76	.48	-.03	.11	-.36, .58
ToT x SEQ x BAR	-.92	-.01	-.33	-1.04, .38	.63	-.02	.21	-.45, .87

Note . *p < .05. **p < .01

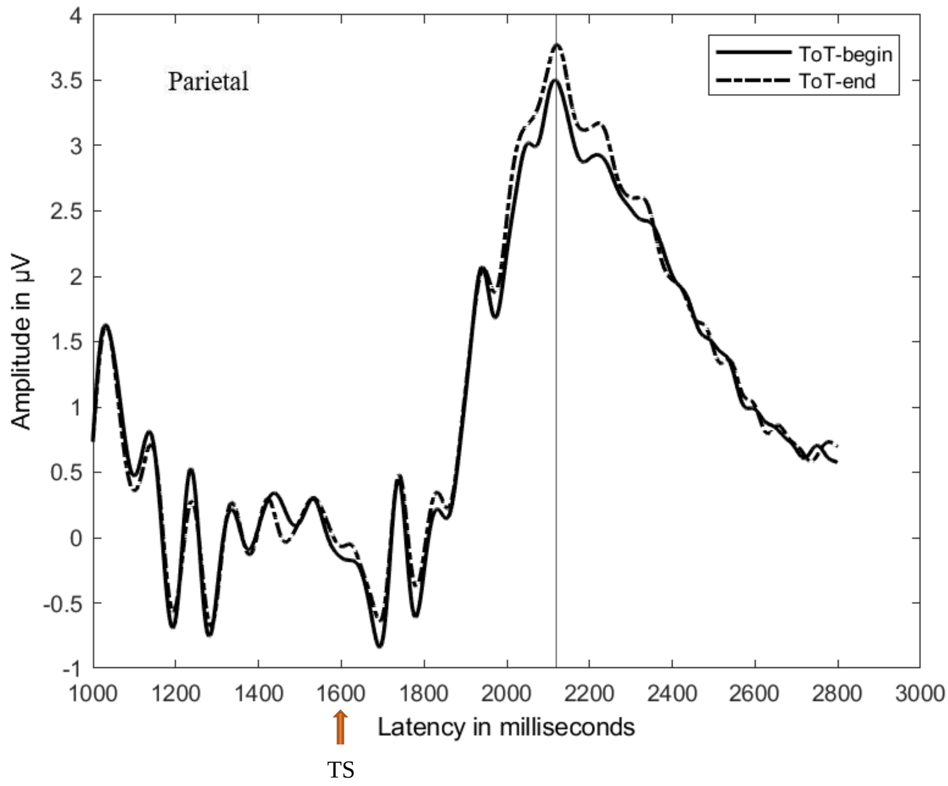

Figure 8. The P3b amplitude superimposed across electrodes Pz, P1, and P2 for the main effect of Time on Task (ToT, that is begin vs. end). Hereby, 0ms refers to the task cue (TC) onset, 800ms refers to the spatial cue (SC) onset, and 1600ms refers to the target stimulus (TS) onset. The xline marks the P3b component.

4 Discussion

The aim of this study was to uncover the effects of feedback about the foreseeable termination of a prolonged task on the modulation of ToT effects in form of a final spurt phenomenon in both performance measures and evoked electrophysiological potentials.

4.1 Motivational effects of the progress bar

Since previous literature has identified that information about the proximate termination of a task can effectively reduce ToT effects (Bergum & Lehr, 1963; Boksem et al., 2005, 2006; Lorist et al., 2005; Wascher et al., 2016), these effects were expected to be less pronounced in blocks presenting a progress bar compared to blocks presenting a static bar. Furthermore, for the former blocks, elevated levels of motivation and task engagement, as well as lower levels of mind wandering were expected (Boksem & Tops, 2008; Brosowsky et al., 2020). Thus, these associations of decreased mental fatigue and increased top-down driven information processing over time due to the use of a progress bar were expected to be reflected in behavioral as well as electrophysiological measures.

Indeed, levels of self-reported measures were significantly higher for motivation and task engagement, as well as significantly lower for mind wandering, for blocks presenting a progress bar compared to blocks presenting a static bar (large effect sizes, d = .77 – 1.38). However, in contrast to these findings and our expectations, the impact of ToT on behavioral and electrophysiological measures was not significantly different between the two bar-conditions except for the ADAN component. The ADAN showed a lower reduction of its amplitude towards the end of blocks presenting a progress bar compared to blocks presenting a static bar (medium effect size, η_p^2 = .14). A reduction in the ADAN could reflect that processes of top-down coordination, control and holding of visuospatial attention were suffering from mental fatigue with increasing ToT (Di Russo et al., 2021). The reduced amplitude decrease could therefore reflect a modulation and, thus, a reduced suffering of visuospatial attention coordination due to the information about the foreseeable task termination provided by the progress bar. However, since this effect was not mirrored in the other investigated ERP/ERL components, the question arises, whether i) the progress bar did not sufficiently elevate motivation in participants, or ii) the progress bar did elevate motivation in participants, however, this additional motivation did neither translate to improved performance nor electrophysiological effects.

Having a closer look at both assumptions, the former one might initially sound more straightforward than the latter one, indicating that the progress bar was not able to sufficiently modulate ToT effects by increasing motivation in participants towards the expected end of a task block. However, as mentioned before, the self-reported measures let indicate otherwise, as participants strongly reported increased motivation and task engagement, as well as less mind wandering. Therefore, it deserves further investigation why potentially elicited motivational effects of the progress bar were not translated into behavioral and electrophysiological effects.

One aspect that can determine the effect of the progress bar is the form in which the information about the progressing time on task is presented to participants. For example, Bergum & Lehr (1963) who successfully induced final performance spurts in behavioral measures of their experimental group provided their participants with clocks as well as the information how long precisely the task would last. Therefore, participants precisely knew during the execution of the task how many minutes it would still last. Similarly, in the studies using clock-speed manipulations that were meta-analyzed by Thönes et al. (2018), participants were presented with commonly designed clocks, therefore providing certain temporal units (e.g., minutes). With these units, participants had a rather precise idea of the remaining time of the task, affecting a person's perception of time passage, their 'internal clock' (Gibbon, Church, & Meck, 1984). This is also supported by the pacemaker-accumulator model that states that the amount of "completed" temporal units positively correlates with the perceived duration of an event (Gibbon et al., 1984). In contrast, the progress bar used in the current experiment did not contain units which participants could have used to precisely measure the perceived duration of the task. Therefore, the question arises how well the filling of the progress bar correlated with participants perception of the task's duration. Direct feedback about the remaining time (e.g., 5 minutes/units) can have a different effect on the motivation and mental fatigue of participants compared to a filling of a progress bar which's progress could be not directly noticeable.

Li, Liu, Ji, and You (2021) analyzed the presentation of progress bars and, in line with this assumption, provided evidence that in addition to a linear filling of the bar, the presentation of percentages of how much of the task has been completed were associated with higher levels of preference and speed perception in participants compared to the mere filling of the progress bar. Based on further findings of related literature, the authors concluded that direct and unambiguous feedback is preferred over vague information. The underlying reason of this preference is the perception of not losing control of the perceived progress of time since uncertainty will result in slower subjective perception of time passage (Branaghan & Sanchez, 2008; Cassidy & MacDonald, 2010; Li et al., 2021). In addition, adding units as percentages to a filling progress bar can facilitate individuals to estimate the remaining time of a task with a glance and therefore reducing further estimations and mental effort (Li et al., 2021; Martinez-Peñaranda, Bailer, Barreda-Ángeles, Weiss, & Pereda-Baños, 2013).

Thus, participants retrospectively felt motivated by the progress bar as indicated by the self-reports. However, this effect might not have been strong enough during the experiment to be reflected in behavioral or electrophysiological measures as the remaining duration of the task could not have been precisely estimated.

4.2 ToT effects

With respect to the missing translation of motivational effects of the progress bar into behavioral and electrophysiological data, the question arises whether mental fatigue was not sufficiently induced in participants to allow a modulation of ToT effects, therefore covering motivational effects. However, in line with our hypothesis, participants' performance was found to decline over the course of the experimental blocks in that response times mildly, yet significantly, increased (medium effect size, $\eta_p^2 = .12$) and the initial difference between repetition and switch trials decreased (medium effect size, $\eta_p^2 = .20$). In addition, the P2 and ADAN amplitude for the task cue were found to decline with increasing ToT (small to medium effect size, $\eta_p^2 = .10$ and $\eta_p^2 = .13$, respectively), indicating increased mental fatigue in participants. This could mirror the performance deterioration by indicating reduced information encoding from the working memory (Lefebvre et al., 2005) and reduced coordination and control of top-down visuospatial attention (Di Russo et al., 2021). This replicates findings by previous studies in which both the response time and P2 amplitude were identified as reliable correlates of ToT and passive task-related mental fatigue (Arnau et al., 2017; Boksem et al., 2005; Freunberger et al., 2007; Lorist, 2008).

However, although ToT effects seem to have been moderately induced in participants, this has not been translated to all ERP/ERL components. In contrast to our hypothesis, no significant differences in the N2 amplitude were found. Only the typical trial sequence main effect was reflected, showing reduced amplitudes for repetition compared to switch trials, indicating increased action monitoring and control for the latter trials. This tendency has also been shown in previous research (Gajewski et al., 2010) and was mirrored in the behavioral measures in that response accuracy was higher for repetition trials compared to switch trials (medium effect size, $\eta_p^2 = .17$). The missing changes in the N2 with increasing ToT indicate that participants' top-down driven action control (Gajewski & Falkenstein, 2014) has not significantly suffered from the task duration, which points against a clear effect of increasing mental fatigue. In addition, the significant decrease in response times for switch trials with increasing ToT (large effect size, $\eta_p^2 = .46$) and reduced P2 amplitude for the switch compared to repetition trials (small to medium effect size, $\eta_p^2 = .09$) indicate that ToT has been confounded by a learning effect to switch between task sets. This has been already observed to occur in task-switching paradigms (Bherer et al., 2008), for example in the form of developing a more effective response suppression, and is in line with research suggesting that cognitive control can be positively affected by processes of learning (Braem et al., 2019).

Regarding a translation of a ToT effect to the P3b, the amplitude at target stimulus onset did not decrease as hypothesized but increased with longer ToT (medium effect size: $\eta_p^2 = .12$), indicating increased demand on higher order-processes of cognitive control. On the one hand, it could be that ToT effects have been differently reflected in the P3b amplitude compared to previous studies. Although the Posner cuing-task switching paradigm was of a simple nature, strategic higher-level mental processes could have suffered from the increasing mental fatigue and therefore required higher cognitive resource allocation at target stimulus-onset. This would also be in line with the moderately high ratings of participants regarding the perceived task demand. Although a further literature review did not reveal a positive association between the P3b amplitude and mental fatigue, further support is provided by multiple studies that identified an increasing P3b for controlled compared to automatic information processing (Hoffman, Simons, & Houck, 1983; Romero & Polich, 1996; Staub, Doignon-Camus, Marques-Carneiro, Bacon, & Bonnefond, 2015). This tendency could also be reflected in the interaction between the trial sequence and ToT (medium effect size: $\eta_p^2 = .20$), presenting decreasing response times for switch trials and increasing response times for repetition trials with increasing ToT. Thus, a performance deterioration in the repetition trials might reflect decreasing lower-level action control, whereas the performance improvement in switch trials might reflect increasing demands on higher-level action control.

On the other hand, ToT effects might have been less strongly pronounced compared to previous studies due to differences in the task paradigm used. Although Lorist et al. (2000) have previously used a task switching paradigm to elicit a decreasing P3b amplitude with increasing ToT, the alteration between tasks has been fixed on every second trial, therefore well predictable for participants. This difference in task switch predictability could have required lower levels of continuous attentional control compared to the present study. However, most studies that presented the same findings in respect to the P3b amplitude have used Go/No-Go and Simon-task paradigms (Möckel et al., 2015; Olofsson & Polich, 2007; Staub et al., 2015). This difference, especially with respect to the variety in task sets and continuous but non-predictably timed task switches, could have been partly responsible for the mixed findings, as the Posner cueing-task switching paradigm might have kept participants too interested and occupied to induce stronger passive task-related mental fatigue.

Thus, a ToT effect seems to have been moderately induced in participants as mostly reflected by the performance deterioration, but also by the P2, ADAN, and P3b amplitude changes over time. However, the ToT effect appears to have been confounded by a learning effect to switch between task sets and has not been translated to all analyzed ERP components as predicted. This might have been partly due to a strong demand on high-level mental processes by the paradigm and variety in task sets used.

4.3 Limitations

The fact that the design of the progress bar potentially limited the emergence of final spurt phenomena cannot unambiguously be supported with evidence based on the data presented. Nevertheless, limitations of the study itself can be formulated.

Firstly, the blocks’ length of 4.27 to 10.67 minutes (M = 7.47 minutes), might have been too short to effectively induce mental fatigue, thus, to significantly affect top-down driven cognitive processes, and to cancel out confounding variables of learning effects that potentially masked stronger behavioral and electrophysiological ToT effects. For example, Möckel et al. (2015) instructed participants to conduct a monotonous and repetitive task for 210 minutes in total (3 blocks of 70 minutes each) and noticed unspecific modulations of learning effects during the first 20 minutes of each experimental sub-block. Other studies investigating ToT effects used similar total task and block lengths (Arnau et al., 2017; Boksem et al., 2005, 2006). Besides the significant reduction of the block duration in the present study, the fatigue-recovering effect of the short breaks (Arnau et al., 2017), and the variety-providing picture-task between blocks could have additionally diminished the ToT effects and mental fatigue. However, ToT effects were nevertheless successfully observed in behavioral and three electrophysiological measures.

Furthermore, no data were acquired regarding subjective levels of mental fatigue that could have served as an additional self-reported factor to investigate evoked ToT effects and potential modulating effects of the progress bar. However, in the present study, levels of mental fatigue could be interpreted indirectly from the behavioral and electrophysiological measures Also, asking participants repeatedly about their level of fatigue might have caused a confounding variable of introspection, potentially causing increased task withdrawal. Lastly, although participants reported to have paid much attention to the progress bar, no objective measure was taken to confirm this over course of the experiment, especially towards the end of blocks, which might affect the effect of the progress bar itself.

4.4 Practical implications and future research

Due to the mixed results and potential confounding effects as discussed above, the formulation of practical implications is limited and formulated with caution. The present study indicated that the progress bar was moderately able to modulate ToT effects for visuospatial attention and to elevate motivation and task engagement in participants retrospectively. Therefore, the practical implication of emphasizing the remaining task duration in everyday settings or industry settings involving spatial navigation and prolonged task performance could be promising in order to limit ToT effects and resulting human errors or accidents. However, the study raised new questions in terms of the design of the progress bar as a potential confounding effect.

For future research of final spurt phenomena, it is therefore recommended that presentation of the progress bar should include certain temporal units, for instance 10 or 20 percentage steps to allow participants to establish a subjective perception of the progressing time. Also, the progress bar could be used as a between-subject factor. Furthermore, it is recommended to use a block design similar to Möckel et al. (2015) with regards to the blocks' length being of approximately 70 minutes and total task length being of approximately 210 minutes to induce stronger mental fatigue in participants. Besides the fact that learning effects in regard to the task cues are less likely to mask ToT effects in longer compared to shorter blocks, ToT effects should also be increased by the lower trial-break ratio within the experiment due to the lower fatigue-recovering effect of the short breaks (Arnau et al., 2017). In addition, eye tracking can be used to check participants attention towards the progress bar, especially at the end of each trial block, as intended and hypothesized (Bergum & Lehr, 1963).

4.5 Conclusion

The subjective data reported by the participants provide evidence that the progress bar had a positive effect on task engagement and motivation, as was hypothesized. However, no significant interaction of ToT and the progress bar emerged in the behavioral or electrophysiological data, besides a single component. These rather mixed results might be due to the fact that a number of interacting processes have a significant influence on ToT and final spurt effects, including the duration of continuous task performance, learning effects, the variety of used task sets and the representation of the progress bar. The progress bar might have not been designed in an ideal way to provide participants with precise information about the remaining duration of the task. The lack of temporal units that can be positively related to the individuals perception of time passage could have been a critical aspect which deserves further investigation, especially since previous studies clearly indicated positive effects of information about the proximate termination of a task on an individual's motivation and mental fatigue (Bergum & Lehr, 1963; Boksem et al., 2005, 2006; Lorist et al., 2005; Wascher et al., 2016).

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Appendix I – Informed consent

Experiment zu Aufmerksamkeitsprozessen und Verarbeitung von Bildern: Informationen für Teilnehmende

Vielen Dank für deine Teilnahme an unserem Experiment! Bevor wir beginnen, möchten wir dich auf folgende Punkte hinweisen:

Freiwilligkeit

Die Teilnahme an dieser Untersuchung ist freiwillig. Die Teilnahme kann jederzeit ohne Angabe von Gründen widerrufen werden, ohne dass Ihnen daraus Nachteile entstehen. Auch eine laufende Untersuchung wird auf Ihren Wunsch hin jederzeit abgebrochen.

Zweck der Untersuchung

Ziel dieser Untersuchung ist zu verstehen, wie Aufmerksamkeitsprozesse ablaufen und wie Bilder verarbeitet werden. Die Untersuchung dient nicht der medizinischen Diagnostik oder Therapie. Die Ergebnisse der Untersuchung helfen uns, die Arbeitsweise des gesunden menschlichen Gehirns zu verstehen.

Datenschutz

Diese Studie wird ausschließlich zu wissenschaftlichen Zwecken durchgeführt. Deine personenbezogenen Daten werden absolut vertraulich behandelt und nicht an unbefugte Dritte weitergegeben, insbesondere gelangen sie nicht an die Öffentlichkeit. Die experimentellen Daten werden pseudonymisiert gespeichert. Dies bedeutet, dass anhand der gespeicherten Daten keine Rückschlüsse auf deine Identität möglich sind. Die Weitergabe, Speicherung und Auswertung der experimentellen Daten erfolgt stets pseudonymisiert.

Messung der elektrischen Hirnaktivität (EEG)

Während des Experiments, wird deine elektrische Hirnaktivität über das Elektroenzephalogramm (EEG) aufgezeichnet. Informationsverarbeitung im Gehirn zeigt sich im EEG anhand von minimalen Abweichungen von der Hintergrundaktivität. Anhand der Stärke der Abweichungen, sowie anhand der Stelle des Kopfes wo sie aufgezeichnet wurden, können wir Rückschlüsse auf die Funktionsweise des Gehirns ziehen. Diese Rückschlüsse sind jedoch nur möglich, wenn die Daten vieler Teilnehmer vorliegen. Rückschlüsse auf die Funktionsweise eines einzelnen Gehirns sind nicht möglich. Die Elektroden, die für die EEG-Aufnahme verwendet werden, sind hochsensibel. Deshalb findet die EEG-Aufnahme in speziellen, elektrisch abgeschirmten Kammern statt. **Bitte überreiche daher vor Beginn des Experiments alle elektrischen Geräte und Uhren, die du bei dir trägst an die Versuchsleiterin/den Versuchsleiter, oder verstaue diese Geräte in deiner Tasche außerhalb der EEG Kammer.**

Ablauf des Experiments

Deine Aufgabe während des Experiments ist es Zahlen zu beurteilen. Je nach Durchgang musst du entweder beurteilen ob eine präsentierte Zahl größer oder kleiner als 5 ist, oder ob sie gerade oder ungerade ist. Welche dieser beiden Aufgaben zutrifft wird in jedem Durchgang durch ein Symbol angekündigt. Zusätzlich kündigt ein Pfeil an, auf welcher Seite des Bildschirms die Zahl mit großer Wahrscheinlichkeit erscheinen wird. Es erscheint immer erst das Symbol das die Aufgabe ankündigt, dann der Pfeil und dann die Zahl die beurteilt werden muss. Die Zahlenaufgabe wird während des Experiments einige Male unterbrochen. Abschnittsweiseweise wird die verbleibende Zeit bis zur nächsten Unterbrechung durch einen Fortschrittsbalken angezeigt.

Während der Unterbrechungen werden dir Bilder auf dem Bildschirm präsentiert. Hier ist deine Aufgabe, jedes Bild danach zu beurteilen wie gut es dir gefällt. Die Beurteilungen können von 1 (gefällt mir gar nicht) bis 9 (gefällt mir sehr gut) reichen. Für diese Antworten steht eine Nummerntastatur zur Verfügung.

Genauere Instruktionen zur Aufgabe erhältst du vor dem Start des Experiments.

Vielen Dank für deine Teilnahme!

Hiermit bestätige ich, dass ich mit den oben genannten Informationen einverstanden bin und diese verstanden habe:

____

(Unterschrift Teilnehmer)

Appendix II – Information about the participant

Fragebogen 1

Geschlecht: ☐ w ☐ m

Alter: ____ Jahre

Höchster Schulabschluss: __________________________

Beruf/Studiengang: __________________________

Leiden Sie an neurologischen oder psychiatrischen Störungen? ☐ ja ☐ nein

Leiden Sie an Schlafstörungen? ☐ ja ☐ nein

Nehmen Sie regelmäßig Medikamente ein bzw. haben Sie heute Medikamente eingenommen?

☐ ja ☐ nein

Wenn ja, welche? ____________________________________

Nehmen Sie Hormone ein? ☐ ja ☐ nein

Wenn ja, welche? ____________________________________

Treiben Sie Sport? ☐ ja ☐ nein

Wenn ja, welchen Sport? ____

Wie viele Stunden pro Woche circa? _____________________________

Rauchen Sie? ☐ ja ☐ nein

Wenn ja, wie viele Zigaretten pro Tag rauchen Sie normalerweise? _____

Wenn ja, haben Sie heute schon geraucht? ☐ ja ☐ nein

Wie viel haben Sie heute gefrühstückt?

☐ gar nicht ☐ wenig ☐ normal ☐ mehr als normalerweise

Haben Sie heute bereits Kaffee oder schwarzen Tee getrunken? ☐ ja ☐ nein

Wenn ja, wie viele Tassen? _______

Tragen Sie eine Brille oder Kontaktlinsen? ☐ ja ☐ nein

Wenn ja, wie viel Dioptrien? _______

Haben Sie schon einmal an einem EEG-Experiment teilgenommen? ☐ ja ☐ nein

Wann sind Sie gestern Abend schlafen gegangen? ___ : ___ Uhr

Wann sind Sie heute Morgen aufgestanden? ___ : ___ Uhr

Wie viel Schlaf hatten Sie in etwa vergangene Nacht? ___ h, ___ m

Um wie viel Uhr gehen Sie normalerweise schlafen? ___ : ___ Uhr

Um wie viel Uhr stehen Sie normalerweise morgens auf? ___ : ___ Uhr

Wie lange schlafen Sie normalerweise pro Nacht? ___ h, ___ m

Appendix III – The Edinburgh Handedness Inventory (translated to German)

Fragebogen 2

Bitte geben Sie die Hand an, mit der Sie bevorzugt die genannte Tätigkeit ausführen. Kreuzen Sie dafür bitte ein entsprechendes Kästchen an. Wenn die Bevorzugung einer Hand so stark ist, dass Sie nur unter Zwang die andere Hand benutzen würden, kreuzen Sie bitte zwei entsprechende Kästchen an. Wenn Sie sich unsicher sind, welche Hand Sie bevorzugen, kreuzen Sie bitte ein Kästchen für links und ein Kästchen für rechts an.

Schreiben	☐ ☐ links	☐ ☐ rechts
Zeichnen	☐ ☐ links	☐ ☐ rechts
Werfen	☐ ☐ links	☐ ☐ rechts
Schere	☐ ☐ links	☐ ☐ rechts
Zahnbürste	☐ ☐ links	☐ ☐ rechts
Messer (ohne Gabel)	☐ ☐ links	☐ ☐ rechts
Löffel	☐ ☐ links	☐ ☐ rechts
Besen (obere Hand)	☐ ☐ links	☐ ☐ rechts
Streichholz (Hand an Streichholz)	☐ ☐ links	☐ ☐ rechts
Schachtel öffnen (Hand an Deckel)	☐ ☐ links	☐ ☐ rechts

Welchen Fuß benutzen Sie zum Fußball kicken?	☐ ☐ links	☐ ☐ rechts
Welches Auge benutzen Sie, wenn Sie nur eines benötigen?	☐ ☐ links	☐ ☐ rechts

Appendix IV – Follow-up questionnaire

Nachbefragung

Vielen Dank noch einmal für deine Teilnahme! Für die zukünftige Gestaltung unserer Experimente bitten wir dich nun noch um ein abschließendes Feedback.

Feedback zur Zahlenaufgabe

Wie anspruchsvoll empfandst du die Zahlenaufgabe?

gar nicht anspruchsvoll sehr anspruchsvoll

Wie sehr musstest du dich anstrengen um die Zahlenaufgabe zu bearbeiten?

gar keine Anstrengung sehr große Anstrengung

Wie häufig bist du bei der Zahlenaufgabe mit den Gedanken abgeschweift?

niemals sehr häufig

Wie motiviert warst du die Zahlenaufgabe zu bearbeiten?

gar nicht motiviert sehr motiviert

Wie sehr warst du bei der Bearbeitung der Zahlenaufgabe in die Aufgabe vertieft?

gar nicht vertieft sehr vertieft

Wie sehr hast du bei der Bearbeitung auf den Fortschrittsbalken geachtet, wenn er angezeigt wurde?

gar nicht beachtet stark beachtet

Wie stark hat dich der Fortschrittsbalken zusätzlich motiviert die Zahlenaufgabe zu bearbeiten?

gar nicht motiviert stark motiviert

Hast du Anmerkungen zur Zahlenaufgabe?

Feedback zur Bilderaufgabe

Wie anspruchsvoll empfandst du die Bilderaufgabe?

gar nicht anspruchsvoll sehr anspruchsvoll

Wie sehr musstest du dich anstrengen um die Bilderaufgabe zu bearbeiten?

gar keine Anstrengung sehr große Anstrengung

Wie häufig bist du bei der Bilderaufgabe mit den Gedanken abgeschweift?

niemals sehr häufig

Wie motiviert warst du die Bilderaufgabe zu bearbeiten?

gar nicht motiviert sehr motiviert

Wie sehr warst du bei der Bearbeitung der Bilderaufgabe in die Aufgabe vertieft?

gar nicht vertieft sehr vertieft

Wie sehr hat dich die Bilderaufgabe motiviert die Zahlenaufgabe zu bearbeiten?

gar nicht motiviert sehr motiviert

Wie sehr war die Bilderaufgabe für dich eine willkommene Abwechslung zur Zahlenaufgabe?

gar nicht willkommen. sehr willkommen

Hast du Anmerkungen zur Bilderaufgabe?