Dissociating Failures of Sustained Attention

Effect of Reward on Dissociating Failures of Sustained Attention

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Abstract

The effects of motivation and the depletion of cognitive resources on performance in a sustained attention task were investigated. 17 participants completed a modified version of the continuous temporal expectancy task (CTET; O'Connell et al., 2009). Performance on the CTET is a measure of sustained attention. Monetary reward was introduced as a between-subjects manipulation. Overall performance and performance across time served as behavioural measures of general sustained attention and the vigilance decrement, respectively. An electroencephalogram (EEG) was used to measure the neural correlates of behaviour, in particular, the alpha band oscillation. EEG analysis revealed higher alpha power for pre-target misses compared to hits, indicating a phase-dependent influence on sustained attention influenced by motivation levels. The vigilance decrement occurred in both reward and no reward groups, unaffected by rewards alone. Ceiling effects may have weakened the impact of rewards. Task performance variability suggests the need for a larger sample size to enhance reliability. In conclusion, alpha power differences between misses and hits suggest its role in sustained attention. However, reward did not mitigate the vigilance decrement which persisted across groups. Further research with a larger sample size is necessary to gain a deeper understanding of these effects.

Introduction

Reading a book, driving a car, and studying for an exam are just some of the several daily tasks that require sustained attention, the ability to maintain a mindful goal-directed focus in contexts whose repetitive, non-arousing qualities provide little external stimulation (Robertson & O' Connell, 2010). Sustained attention is a crucial cognitive process that impacts various aspects of human performance and everyday functioning; it is a fundamental cognitive ability that enables individuals to stay engaged and vigilant during tasks, even in the face of monotony or distractions (O'Connell et al., 2009). It plays a crucial role in academic and occupational settings, where maintaining focus for extended periods is necessary for learning, problem-solving, and decision-making. In addition, sustained attention is essential for driving, learning, multitasking, and overall productivity in daily life.

Understanding the mechanics of sustained attention, including the factors that contribute to its failures, is essential for optimising attentional processes and addressing attention-related challenges. To assess sustained attention, researchers have employed various tasks, and one commonly used paradigm is the Continuous Temporal Expectancy Task (CTET; O'Connell et al., 2009). The CTET requires participants to continuously monitor stimuli presented over a prolonged period and respond when a specific target stimulus occurs. Performance on the CTET provides a measure of sustained attention, allowing researchers to investigate attentional lapses, fluctuations, and overall task engagement.

The Continuous Temporal Expectancy Task (CTET) is a cognitive task that involves presenting participants with images of faces and cars while measuring their accuracy in responding to target stimuli over time. It is essential to consider potential differences in response accuracy between faces and cars to ensure unbiased results. Research has shown that individuals may have varying levels of expertise or familiarity with different object categories, such as faces or cars. For example, a study by Gauthier and colleagues (2000) demonstrated that participants with experience in car racing showed superior performance in car recognition tasks compared to novices. Similarly, other studies have shown that individuals may have a natural predisposition or affinity towards recognising faces due to their evolutionary significance (Haxby et al., 2000). Therefore, it is crucial to account for these individual differences and potential biases when interpreting results obtained from the CTET or any related tasks to avoid skewed conclusions with regard to sustained attention.

While the depletion of cognitive resources can negatively impact sustained attention (Esterman & Rothlein, 2019), motivation can play a crucial role in sustaining attention and mitigating the vigilance decrement in attention-demanding tasks (O'Connor et al., 2019). Underload Theory proposes that failures in sustained attention can be attributed to factors such as disinterest, boredom, and under-arousal (Esterman et al., 2014). When individuals are not adequately engaged or stimulated by a task, their attention may diminish, leading to lapses and decreased performance. Prior research demonstrates that attention can be enhanced by rewards, which act as motivators and increase arousal levels. This finding supports the idea that rewards can counteract disinterest, boredom, and under-arousal, which are known to contribute to failures in sustained attention (Esterman et al., 2014).

In contrast, Resource Theory, as proposed by Mackworth (1948), suggests that failures in sustained attention primarily stem from the depletion of attentional resources. According to this theory, the finite cognitive resources required for sustained attention can become exhausted over time, leading to a decline in performance. While Resource Theory does not emphasise the role of rewards in enhancing attention, the study by Esterman et al. (2014) highlights the dissociable aspects of sustained attention that can be influenced by rewards. This discrepancy suggests the need to integrate the underload and resource theory to understand sustained attention more comprehensively.

To address this integration, a cost-benefit framework becomes essential. Sustained attention involves both motivational and resource-related influences, as it requires individuals to balance the costs and benefits of continuing a task (Cost-Benefit Theory). By considering the motivational aspect of attention (reward vs. boredom) and the resource-related influences (alertness vs. fatigue), the cost-benefit framework provides a more comprehensive understanding of sustained attention. It acknowledges the interplay between motivation and resource allocation, which are essential factors in determining attentional performance.

Investigating the effect of monetary reward on sustained attention becomes crucial within the context of the cost-benefit framework. Monetary rewards serve as powerful motivators that can enhance sustained attention. By examining the impact of monetary rewards on attentional performance, researchers can gain valuable insights into the interplay between motivation, resource allocation, and sustained attention. This investigation holds promise for various domains, such as education, workplace productivity, and training programs, as it can inform the development of strategies to improve sustained attention and optimise task performance.

In the context of the impact of motivation on sustained attention, the presence of reward does not necessarily enhance sustained attention performance, and the vigilance decrement persists across reward and no reward conditions (Engelmann, 2009; Esterman et al., 2014). This suggests that other factors, such as task demand or individual differences, may modulate the effect of rewards on sustained attention.

Numerous studies have explored the influence of reward on sustained attention and alpha band oscillations, demonstrating its significant impact on these cognitive processes (Hickey et al., 2014). These investigations have revealed that reward has the potential to improve performance in sustained attention tasks by increasing motivation and allocating greater attentional resources (Esterman et al., 2013). Moreover, reward has been shown to modulate alpha band oscillations, which are believed to reflect the allocation of attentional resources and the suppression of irrelevant information (Clayton et al., 2015).

In addition to behavioural measures, studying the neural correlates of sustained attention provides valuable insights into the underlying mechanisms of attentional processes. Electroencephalography (EEG) offers a valuable method for investigating the temporal dynamics of cortical activity and provides insights into the evolving brain states associated with attentional control (Ridderinkhof et al., 2003). EEG has been widely employed in prior research to measure neural activity associated with sustained attention tasks (O'Connell et al., 2009). By capturing the precise timing and amplitude of neural activity, EEG allows researchers to examine the real-time dynamics of attentional processes and gain a deeper understanding of the mechanisms underlying sustained attention. Furthermore, EEG provides the opportunity to investigate how these 7
mechanisms may be modulated by motivational factors such as reward, thereby shedding light on the interplay between attention and motivation.

The alpha band oscillation, specifically, has emerged as a focus of investigation in the context of sustained attention research. Alpha oscillations, typically ranging from 8 to 12 Hz, are prominent in the human brain and have been associated with various cognitive functions, including attention ((O'Connell et al., 2009; Cohen, 2014). EEG studies have demonstrated that alpha power, reflecting the overall magnitude of alpha oscillations, is linked to sustained attention. For example, research has shown that pre-target misses in sustained attention tasks exhibit higher alpha power compared to hits (O'Connell et al., 2009). This finding suggests that alpha power fluctuations play a role in maintaining attention over time. Moreover, the phase-dependent nature of alpha oscillations indicates that the timing and synchronisation of alpha activity influence attentional processes (Klimesch, 2012). By investigating the neural correlates of sustained attention, including the modulation of alpha band oscillations, researchers can gain insight into how reward and motivation impact attentional performance. This knowledge contributes to our understanding of the complex interplay between attention, neural dynamics, and motivational factors in cognitive processes.

The analysis of total alpha power and evoked alpha power provides different insights into the neural correlates of sustained attention and can influence the conclusions drawn from the study. Total alpha power reflects the overall magnitude of alpha oscillations, while evoked power specifically captures the alpha response that is time-locked to a particular stimulus or event; evoked power provides phase-dependent information (Cohen, 2014).

Total alpha power analysis provides a measure of the ongoing alpha activity in the brain, which is associated with the inhibition of sensory processing and is considered to reflect a state of cortical idling or decreased arousal (Klimesch, 2012). Higher total alpha power has been linked to better sustained attention performance and task engagement (Mazaheri & Jensen, 2010). On the other hand, evoked alpha power analysis focuses on the alpha response that is directly elicited by a specific stimulus or event. Evoked alpha power reflects the dynamic modulation of alpha oscillations in response to sensory processing and cognitive demands (Klimesch, 2012). It provides insights into the allocation of attentional resources and the efficiency of stimulus processing (Busch et al., 2009).

Given these findings, an important research question arises: How does reward affect failures in sustained attention and alpha band oscillations? Exploring this question will shed light on the underlying mechanisms by which reward influences sustained attention and alpha band oscillations, including the enhancement of task motivation, attentional resources, and the suppression of irrelevant information.

Methods

Task

The Continuous Temporal Expectancy Task (CTET) is a cognitive task that has been used as a measure of sustained attention. For the experiment, a gray-scale rapid serial visual presentation (RSVP) stream of faces and cars were presented in equal proportion; the non-target stimuli of 800ms are presented 90% of trials, while target stimuli of 1200ms are presented 10% of the time. The CTET requires participants to press a button, based on whether the image is a face or car, as quickly as possible in response to the presentation of a target stimulus that rarely occurs, while ignoring non-target stimuli that are presented commonly (O'Connell et al., 2009). In the experiment, each block consisted of 360 trials, with each of the 10 blocks lasting approximately 5 minutes. This task requires sustained attention as participants must maintain their focus over a long period of time in order to detect the target stimuli.

Participants

A total of N=17, aged 18-20 healthy adult participants were recruited from University of California, Santa Barbara via the SONA System. Participants were included if they were above the age of 18 and were excluded if they reported any uncorrected perceptual or visual impairments. All participants provided written informed consent prior to participation in the study. The participants were randomly assigned to either the reward or no reward condition in a between-subjects design. Participants were compensated for their time with academic credits towards a psychology course. All participants gave written informed consent, and all procedures were approved by the ethical review board of the University of California, Santa Barbara and the International Review Board.

Procedure

Experimental procedures were conducted in a sound-attenuated chamber with dim lighting (40.0V and 3.14A). The viewing distance between the participant and the computer screen was set at 133 cm, while the computer screen width was 55 cm. Additionally, the experiment was conducted in a copper chamber that minimised electrical noise and ensured a controlled environment. The experimental task was presented using MATLAB (The MathWorks, Inc.) and the Psychophysics Toolbox extension (Brainard, 1997; Pelli, 1997). EEG data were recorded using a 64-channel BioSemi ActiveTwo system and ActiView software.
Upon arrival, participants were provided with a consent form to complete. After completing the consent form, participants were asked to leave all personal belongings, including all electronics, in an adjacent room. They were then escorted into the experimental chamber and asked to adjust the chin rest to their convenience. Following adjustment of the chin rest, participants were given instructions regarding the experimental task and asked to complete a practice block of the task. They were instructed to press the 'z' key on the keyboard if the presented image was a car and to press the 'm' key on the keyboard if the presented image was a face. They were instructed that only images that appeared for a longer duration required a response.

In the task, participants were randomly assigned to either the point or reward group, each involving a distinct system to evaluate their performance. During the instructions phase, participants were informed about the specific feedback they would receive based on their assigned group. Correctly identifying and responding to target stimuli, referred to as hits, were rewarded with +10 points; missing a relevant stimulus or responding incorrectly to a non-target stimulus incurred a penalty of -10 points. Additionally, false alarms, which involved responding to short duration stimuli that were not actually targets, resulted in a deduction of -1 point. On the other hand, participants in the reward group were informed via instruction slides that they would receive actual monetary rewards based on their performance; the experimenter remained blind to their assigned condition. Feedback was provided in terms of monetary values, such as dollars. In this case, the point values earned by participants were divided by 0.01, to represent monetary feedback in dollars. For example, if a participant earned 10 points, they would receive 0.1 dollar as feedback. Similarly, deductions for misses or incorrect responses were calculated based on the conversion factor. Feedback from the practice was shown to the experimenter. Participants who had difficulty understanding the instructions or performed below a predetermined performance threshold of -100 were given an additional practice block. If the score remained below -100 after the additional practice, participants were dismissed.

During capping, participants had their head circumference, front-to-back measurement, and ear-to-ear measurement taken to determine the appropriate size of EEG cap and to centre the cap. External electrodes were applied around the eyes and on the mastoids. The EEG cap was placed on the participant's scalp after measuring for size. EEG electrodes were attached to the cap and cables were secured with a Velcro strap. Participants were then moved back into the experimental chamber and EEG data were recorded while they completed ten blocks, of 5 minutes each, of the experimental task. After each block, participants received feedback regarding their performance. Participants were randomly assigned to one of two groups, reward or no reward, depending on which they received monetary compensation or points, respectively.

Following the experimental blocks, participants were asked to complete the BIS/BAS questionnaire, along with other questions concerning their experience during the study, after which they were paid if they were in the reward group.

Results

Behavioural Analysis

A mixed-design ANOVA was conducted to analyse the effect of reward on sustained attention. The analysis utilised a mixed-design ANOVA with a between-subjects factor of condition (reward vs. no reward) and within-subjects factors of 15 bins (representing time intervals of 24 trials per bin) and 10 blocks. The dependent variables assessed were "detection" (proportion of target images detected), "accuracy" (proportion of accurate responses with regard to face and car), and false alarms (proportion of false positive errors).

Across all subjects, the overall mean detection rate was found to be M = 0.768 (SD = 0.422), indicating that participants were generally successful in detecting the target stimuli during the task. The accuracy rate was M = 0.741 (SD = 0.438), suggesting a moderate level of accuracy in correctly identifying the target stimuli. Participants displayed a low false alarm rate of M = 0.004 (SD = 0.061), indicating a minimal tendency to incorrectly identify non-target stimuli as targets.

For the dependent variable of baseline-corrected detections of target images, the ANOVA revealed a significant main effect of bin ($F(14, 210) = 5.813$, $p < 0.001$, partial $\eta^2 = 0.279$), indicating differences in vigilance across the bins. The interaction between feedback condition and bin was also significant ($F(14, 210) = 2.030$, $p = 0.017$, partial $\eta^2 = 0.119$), suggesting that the effect of reward varied across the bins, i.e. across the 360 trials in one block. However, the main effect of reward condition was not significant ($F(1, 15) = 0.109$, $p = 0.746$, partial $\eta^2 = 0.007$), indicating that reward did not have a significant overall effect on sustained attention, as shown in Figure 1.

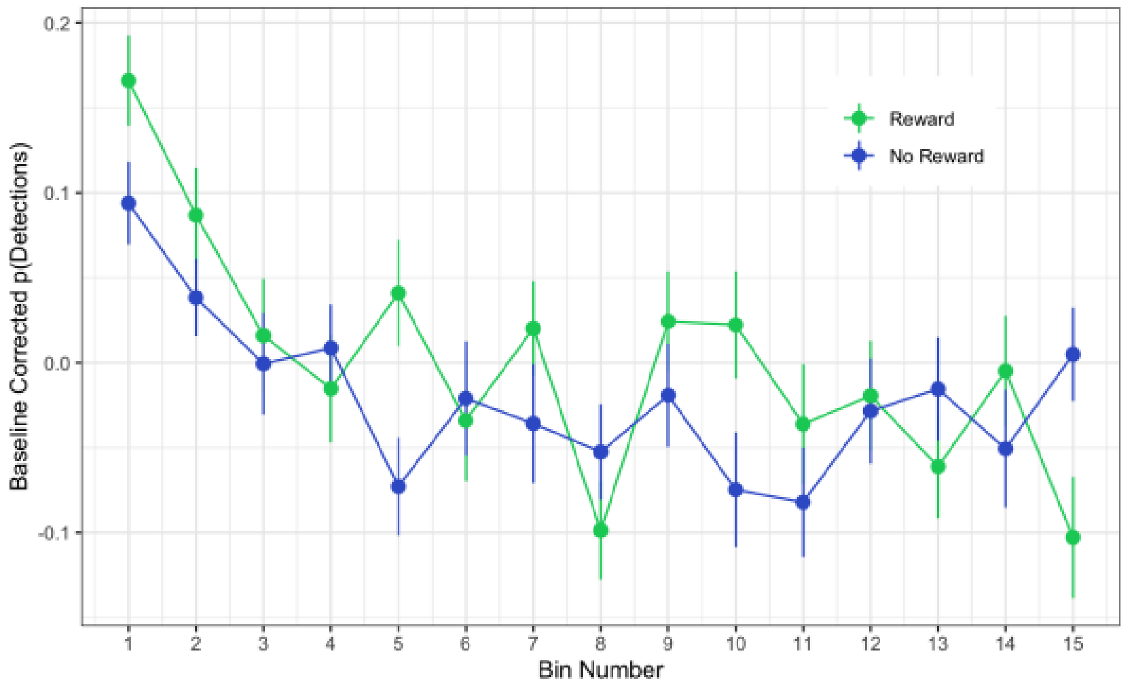

Figure 1. **Shows baseline corrected detections for reward and no-reward participants across each block.**

For the dependent variable of baseline-corrected accuracy, the ANOVA revealed a significant main effect of bin ($F(14, 210) = 4.182$, $p < 0.001$, partial $\eta 2 = 0.218$), indicating differences in accuracy across the bins. The interaction between reward condition and bin was not significant ($F(14, 210) = 1.503$, $p = 0.112$, partial $\eta 2 = 0.091$), suggesting that the effect of reward did not vary significantly across the bins. The main effect of reward condition was also not significant ($F(1, 15) = 0.006$, $p = 0.938$, partial $\eta 2 = 0.0004$), indicating that reward did not have a significant overall effect on accuracy, as shown in Figure 2.

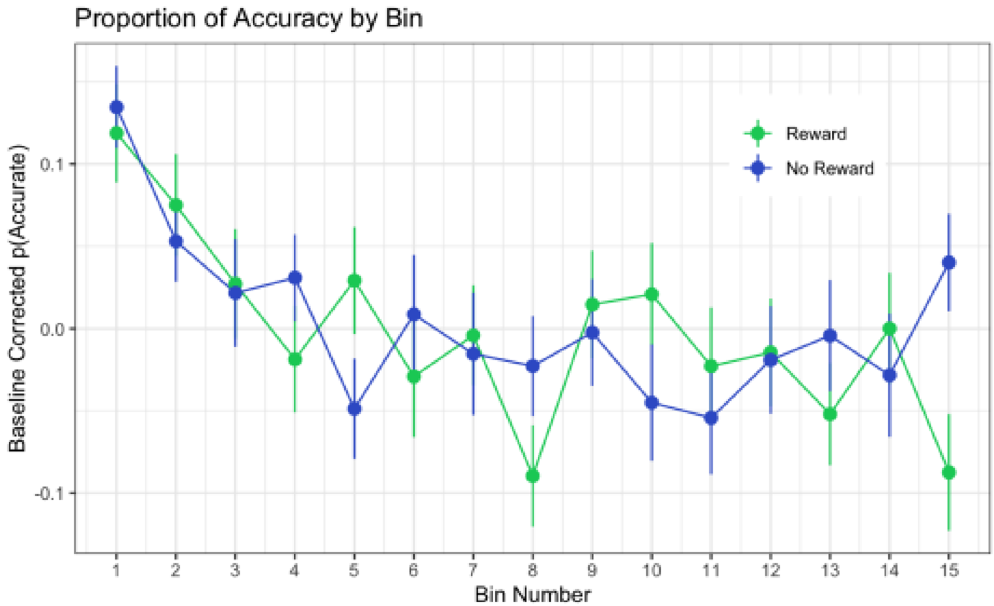

Figure 2. **Shows baseline corrected accuracy for reward and no-reward participants across each block.**

For the dependent variable of baseline-corrected p(false alarm), the ANOVA did not reveal any significant effects ($F = 0.412$, $p = 0.531$, partial $\eta 2 = 0.027$) nor did any interaction effects reach statistical significance. There were no significant main effects of reward condition, bin, or block, and no significant interactions.

Analysing the performance for face stimuli specifically, participants exhibited a detection rate of M = 0.766 (SD = 0.423), demonstrating their ability to successfully detect face targets. The accuracy rate for face stimuli was M = 0.74 (SD = 0.439), indicating a moderate level of accuracy in identifying face targets. Participants displayed a low false alarm rate of M = 0.004 (SD = 0.06), suggesting a minimal tendency to incorrectly identify non-target faces as targets. Regarding car stimuli, participants demonstrated a detection rate of M = 0.77 (SD = 0.421), suggesting successful detection of car targets. The accuracy rate for car stimuli was M = 0.742

(SD = 0.438), indicating a moderate level of accuracy in correctly identifying car targets. Participants displayed a low false alarm rate of M = 0.004 (SD = 0.061), indicating a minimal tendency to incorrectly identify non-target cars as targets. These findings suggest that, overall, participants exhibited moderate accuracy and a low false alarm rate in the CTET, regardless of the stimulus type (faces or cars).

Electroencephalography (EEG) Analysis

The effect of reward on sustained attention was also investigated by analysing the EEG data. The analysis focused on the alpha frequency range (8-12 Hz) using the Fast Fourier

Transform. Epochs ranging from -4000ms to 800ms around the onset of the target stimulus were examined. Statistical analysis was conducted on 9 posterior electrodes- P1, Pz, P2, PO3, POz, PO4, O1, Oz, O2.

Total Power Analysis

The analysis revealed that pre-target misses were associated with greater alpha power compared to hits, both in terms of total alpha power and evoked alpha power. Specifically, a t-test comparing hits and misses across both feedback conditions (i.e., reward and no reward) for total alpha power did not show a significant difference ($t = -1.343$, $df = 16$, $p = 0.198$); however pre-target misses showed a numerically higher alpha power compared to hits. Further examination within specific conditions indicated that in the reward group, the t-test comparing hits and misses for total alpha power also did not reach statistical significance ($t = -1.666$, $df = 7$, $p = 0.14$). Similarly, in the no reward group, the t-test comparing hits and misses for total alpha power did not yield a significant result ($t = -0.077$, $df = 8$, $p = 0.941$).

To explore the effects of both the feedback condition (reward vs no reward) and trial outcome (hits vs. misses) on total alpha power, an ANOVA was conducted. The ANOVA results showed no significant main effect of reward ($F = 0.001$, $p = 0.981$), hits vs misses ($F = 2.123$, $p = 0.166$), or their interaction ($F = 1.878$, $p = 0.191$). These findings indicate that the differences in total alpha power between hits and misses were not significantly influenced by the feedback condition.

Evoked Power Analysis

To assess the statistical significance of the evoked alpha power differences, t-tests were performed. In the reward group alone, the t-test comparing hits and misses did not reach statistical significance ($t = -1.594$, $df = 7$, $p = 0.155$), suggesting no significant effect. However, in the no reward group, the t-test comparing hits and misses revealed a significant negative effect ($t = -2.950$, $df = 8$, $p = 0.0184$), indicating a significant difference between hits and misses within that group.The t-test comparing hits and misses across both feedback conditions (i.e., reward and no reward) showed a significant negative effect ($t = -3.209$, $df = 16$, $p = 0.00547$), indicating a significant difference between the two groups.

Furthermore, an ANOVA was conducted to examine the effects of both the feedback conditions and hits vs. misses on evoked alpha power. The ANOVA revealed a significant main effect of hits vs. misses ($F = 10.554$, $p = 0.005$), indicating that hits vs. miss had an impact on evoked alpha power. The main effect of the feedback condition did not reach statistical significance ($F = 2.141$, $p = 0.164$). The interaction between the feedback condition and hits vs misses also did not reach statistical significance ($F = 2.389$, $p = 0.143$).
Comparing pre-target misses and hits, a significant difference in evoked alpha power was found. Further analysis showed that this effect was driven by the hits vs misses, indicating that

the effect of evoked alpha power varied depending on the specific condition. No significant main effect of condition was observed (F = 2.141, p = 0.164). However, a significant main effect of hits vs misses was found (F = 10.554, p = 0.005), indicating that the type of condition influenced evoked alpha power. The interaction between condition and hits vs misses did not reach statistical significance (F = 2.389, p = 0.143). Effect size analysis revealed moderate effect sizes for the main effect of hits vs misses.

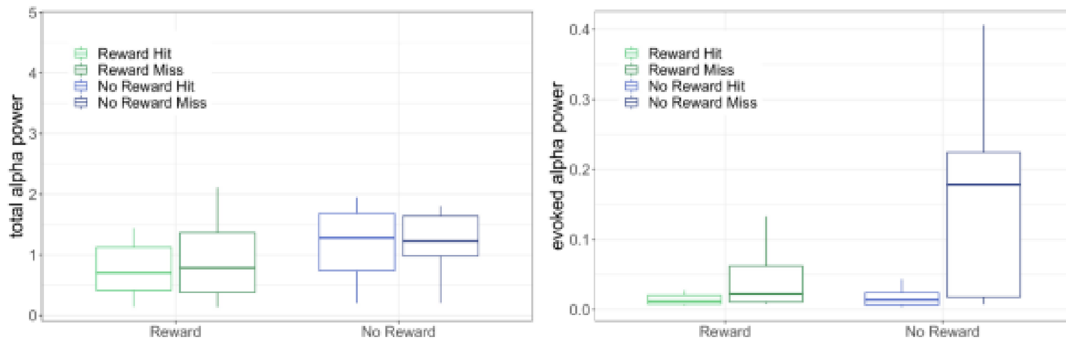

Figure 3. **The boxplots allow for a visual comparison of the total and evoked alpha power between the Reward and No Reward conditions. Evoked alpha power for the no reward groups' misses is significantly higher than for the reward group.**

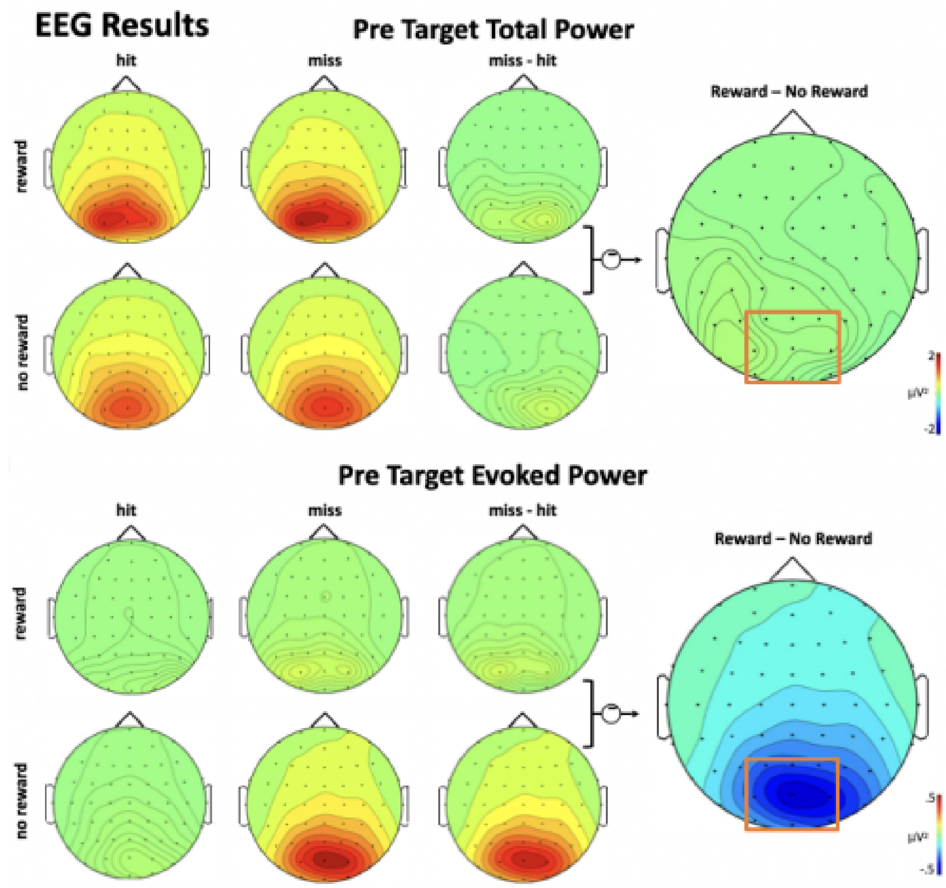

Figure 3. A topoplot visualisation of total and evoked alpha power displayed distinct patterns for reward and no reward conditions. Total and evoked alpha power showed a greater difference between pre-target miss and hit trials. Specifically, the difference between miss and hit trials was greater in the no reward group for evoked power. These findings suggest that the influence of alpha power on sustained attention may vary based on phase, as evoked power is a phase dependent measure.The orange box indicates the 9 electrodes analysed and included in the statistics.

Discussion

The present study investigated the effect of reward on failures of sustained attention using a combination of behavioural analysis and electroencephalography (EEG) analysis. The behavioural analysis focused on measures of detection, accuracy, and false alarms, while the EEG analysis examined total and evoked alpha power, in relation to detection (hits vs misses), as indicators of neural oscillatory activity.

Regarding the behavioural analysis, the results indicated a significant main effect of bin, time across a block of the task, for both detection and accuracy measures, suggesting differences in vigilance across the time intervals of the task. However, the interaction between feedback condition and detection is only significant across bins, indicating that the effect of reward varied across different time intervals. Importantly, the main effect of feedback condition was not significant for either detection or accuracy, indicating that reward did not have a significant overall effect on sustained attention. Overall, the results indicate that the vigilance decrement persisted regardless of feedback condition, and reward did not have a significant overall effect on failures of sustained attention, which is consistent with previous literature (Esterman et al., 2014).

Furthermore, the analysis of false alarms did not reveal any significant effects or interactions, indicating that reward did not influence the tendency to incorrectly identify non-target stimuli. The low false alarm rates observed in the study suggest that participants were generally successful in distinguishing between target and non-target stimuli, regardless of the feedback condition. These results are in line with previous studies that have reported low false alarm rates in similar attention tasks (Sarter et al., 2001).

The EEG analysis focused on alpha power in the 8-12 Hz frequency range, examining both total and evoked alpha power. The analysis revealed that pre-target misses were associated with greater alpha power compared to hits, indicating a potential link between alpha oscillations and failures of sustained attention. However, the effect of evoked alpha power varied depending on the reward condition. Specifically, the no reward group showed a significantly greater difference in evoked alpha power between misses and hits, suggesting a reward-dependent modulation of alpha oscillations. These findings support previous studies that have implicated alpha oscillations in sustained attention and their modulation by reward-related factors (Anderson et al., 2017). The impact of alpha power on sustained attention is influenced by the presence or absence of reward, with reward-related conditions showing specific patterns of alpha power modulation. The results indicate a complex relationship between reward, sustained attention, and neural oscillatory activity in the alpha frequency range.

Analysis of both total and evoked alpha power revealed greater alpha power for pre-target misses compared to hits. Specifically, the evoked alpha power exhibited a significant difference between misses and hits. Further examination within specific conditions showed that the no reward group had a greater miss-hit difference in evoked alpha power. These findings may suggest a phase-dependent influence of alpha oscillations on sustained attention, and the degree of this phase dependency may vary depending on the levels of motivation.

In summary, the analysis of EEG data showed that pre-target misses were associated with greater alpha power compared to hits, both in terms of total and evoked activity. The effect of evoked alpha power varied depending on the feedback condition, with a significant difference observed in the no reward group. These findings suggest that alpha oscillations play a role in modulating sustained attention, and this modulation may be influenced by reward, namely, monetary motivation.
A comparison between pre-target misses and hits revealed a greater alpha power for pre-target misses in both total and evoked activity. Specifically, the miss-hit difference in alpha power was significantly higher in the no reward group, indicating an effect of alpha on sustained attention that may depend on the phase. Notably, the phase dependency of this influence on sustained attention varied depending on the levels of motivation.

The finding of greater alpha power for pre-target misses compared to hits in the total alpha range suggests a potential disengagement or reduced attentional allocation during the processing of missed targets. This finding aligns with previous research indicating that alpha power increases when attention lapses or when individuals fail to detect salient stimuli (Sadaghiani & Kleinschmidt, 2016). Thus, the observed difference in total alpha power between hits and misses may indicate lapses in sustained attention during the task.

The results of the experiment indicate that both the reward and no reward groups exhibited a vigilance decrement, suggesting a decline in sustained attention over time. The presence of reward did not mitigate this decrement, indicating that the effect of reward on sustained attention was not significant in this context. It is important to note that the task performance showed high variability, which may have been a contributing factor to the lack of a significant effect of reward. This variability suggests that a larger sample size may be required to obtain more reliable conclusions. Furthermore, the presence of ceiling effects, where participants may have already reached their maximum performance level, could have attenuated the potential impact of reward on sustained attention. These findings highlight the need for further investigation and potentially a larger sample size to gain a better understanding of the effect of reward on sustained attention in this task.

The present study leaves room for several future studies that should be acknowledged. Firstly, the sample size was relatively small, which may have limited the statistical power to detect significant effects. Increasing the sample size in future studies would provide a more robust evaluation of the effect of reward on sustained attention. Second, the study utilised a specific reward manipulation (monetary reward) compared to a point system, and the generalisability of the findings to other types of rewards or motivation contexts is uncertain. Future research could explore different reward modalities or motivational factors to further elucidate the relationship between reward and sustained attention. Additionally, the present study focused on alpha oscillations, but other frequency bands, such as theta or gamma, may also play a role in sustained attention. Investigating the interplay between different frequency bands and reward-related factors would provide a more comprehensive understanding of the underlying neural mechanisms.

In conclusion, the results of the current study suggest that reward does not have a significant overall effect on failures of sustained attention, as measured by behavioural performance. However, the EEG analysis revealed that alpha oscillations, particularly evoked alpha power, may be modulated by reward-related factors. These findings contribute to the growing body of literature investigating the interplay between reward, sustained attention, and neural oscillatory activity. Future research should aim to replicate and extend these findings, considering larger sample sizes, different reward manipulations, and a broader range of frequency bands, to gain a more comprehensive understanding of the complex relationship between reward, sustained attention, and neural mechanisms.

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