Article

Not peer-reviewed version

The Impact of State Depression on Proactive Control and Distractor Processing in a Memory Task: An Electrophysiological Study

Giorgio Fuggetta * , Philip A. Duke , Rajanya Chakraborty , Parthasarathi Murugesan , Jacopo Cocciarelli , Elvis Delibashi

Posted Date: 19 February 2025

doi: 10.20944/preprints202502.1543.v1

Keywords: state depression; perceptual load; visual attention; suppression; selective attention, top-down control; event-related brain potential; early PD; N2pc

Article

The Impact of State Depression on Proactive Control and Distractor Processing in a Memory Task: An Electrophysiological Study

Giorgio Fuggetta [1,*], Philip A. Duke [2], Rajanya Chakraborty [1], Parthasarathi Murugesan [1], Jacopo Cocciarelli [1] and Elvis Delibashi [1]

[1] School of Psychology, University of Roehampton, Whitelands College, Holybourne Avenue, London, SW15 4JD, United Kingdom
[2] School of Psychology and Vision Sciences, University of Leicester, University Road, Leicester, LE1 7RH, United Kingdom
* Correspondence: giorgio.fuggetta@roehampton.ac.uk

Abstract: (1) *Background*: Individuals with high levels of state depression are hypothesized to have an impairment of attentional control functions necessary for filtering irrelevant information. This study used the event-related potential of early P_D, a marker of distractor suppression and N2pc, an indicator of attentional capture, to investigate whether high state depression affects selective attention to ignore or suppress distractors. (2) *Methods*: Thirty-three undergraduate students completed the Depression Anxiety Stress Scales—21 (DASS-21; Lovibond & Lovibond, 1995) and performed a modified delayed match-to-sample task. Participants encoded abstract shapes under low- or high-perceptual load conditions in visual working memory while ignoring a lateralized Chinese character as task-irrelevant distractor. (3) *Results*: Individuals with high-state depression, failed to suppress the distractor, evidenced by the absence of early P_D. Under low-perceptual load, they also displayed a significant N2pc component, indicating attentional allocation to the distractor. In contrast, low-state depression participants, successfully suppressed the distractor, showing early P_D and absence of N2pc. (4) *Conclusions*: These findings suggest that high-state depression individuals have an impairment top-down attentional control, particularly in feature-based selective attention. This deficit hinders the ability to filter out irrelevant information, potentially contributing to cognitive difficulties associated with depression.

Keywords: state depression; perceptual load; visual attention; suppression; selective attention; top-down control; event-related brain potential; early P_D; N2pc

1. Introduction

Deficits in top-down attention, particularly selective attention, are well-documented in individuals with Major Depressive Disorder (MDD) (for a review see [1]). Top-down attention refers to the guided allocation of attentional resources based on prior knowledge, goals, and plans [2]. A critical subdomain, selective attention, allows individuals to focus on task-relevant information while suppressing irrelevant distractions [3]. Impairments in selective attention can significantly impact daily functioning and provide insight into the cognitive mechanisms underlying MDD.

Research demonstrates that individuals with MDD often exhibit deficits in feature-based selective attention, which involves prioritizing specific attributes (e.g., color or shape) of stimuli while ignoring distractions. For example, slower reaction times and poor performance on the non-emotional Stroop color-word task have been linked to reduced functional connectivity within the fronto-parietal attention network, as evaluated with fMRI and decreased parietal alpha power, as measured with resting state EEG with eyes closed, predisposing individuals with worse attentional focus to developing depression [4]. In contrast, spatial selective attention, which prioritizes specific

 doi:10.20944/preprints202502.1543.v1

locations, appears relatively preserved in MDD, as evidenced by tasks like the Flanker paradigm showing no significant differences between MDD and healthy controls [5,6]. These findings suggest that attentional impairments in MDD are domain-specific, warranting further investigation into the mechanisms governing feature-based selective attention.

A group of individuals experiencing persistent negative mood, lack of enjoyment, low self-esteem, and anhedonia, characteristics typically associated with more enduring depressive tendencies, and a matched control group, participated in the current study which aimed to investigate the neurophysiological effects of attentional allocation and distractor processing under varying visual working memory (VWM) loads. VWM is a capacity-limited system that maintains visual information for short durations to support ongoing tasks [7,8]. Using a modified version of a delayed match-to-sample task [9], participants were required to encode and retain either one or four complex objects (abstract shapes) in VWM while ignoring a lateralized task-irrelevant complex distractor object (Chinese character). The singleton distractor object, a lateralized stimulus that differed in shape dimension from the other task-irrelevant homogeneous items (circles) in a circular visual array, was presented during the retention interval, and participants' ability to resist its attentional capture was examined using electrophysiological measures.

This study is grounded in Lavie's Perceptual Load Theory (PLT; [10,11]), which posits that the perceptual load of a task, referring to the complexity and numerosity of the physical stimuli, determines the extent of distractor processing. According to the PLT, perception is proposed to be an automatic process that continues until the limited perceptual capacity is fully exhausted. Under low perceptual load (e.g., encoding and maintaining one complex object in VWM), excess attentional resources may spill over, allowing irrelevant stimuli to capture attention. In contrast, high perceptual load (e.g., encoding and maintaining four complex objects in VWM) depletes attentional capacity, reducing or eliminating distractor processing. Although PLT has been supported mainly by behavioral studies (e.g., [12]), its neurophysiological underpinnings remain somewhat underexplored.

Event-related potentials (ERPs) provide a valuable tool for investigating with direct electrophysiological measures, the temporal dynamics of attentional processes. A systematic evaluation of ERP studies has reported perceptual load effects as predicted by the PLT at all processing stages. Findings are, however, mixed, and this inconsistency is especially observed for earlier ERP components (i.e., C1, P1, and N1) but also seen during later stages (i.e., P2, and N2) (See for review [13]). In this study, we evaluated two lateralized ERP components of early P_D and N2pc which measure distinct aspects of attentional selection and control under low- and high-perceptual load conditions. The N2pc is observed as a negative deflection that is larger contralateral to the attended stimulus and reflects the neural process of orienting and focusing covert attention on peripheral object features among competing distractors and indicative of attentional capture by salient stimuli [14–17]. Research utilizing magnetoencephalographic (MEG) recordings has identified two distinct neural sources contributing to the N2pc: the Early Parietal Source, between 180–200 ms after stimulus onset, associated with the initiation of attentional shifts within the visual field, and the Later Occipito-Temporal Source, between 220–240 ms after stimulus onset, thought to reflect the focusing of attention, implemented by extrastriate areas of the occipital and inferior temporal cortex [18].

In the current electrophysiological study, we are primarily formulating our hypotheses based on the fundamental assumption of PLT [10,19–22]. Thus, according to the PLT, regardless of individual differences in state depression, in the low-perceptual load condition, as there should be spare perceptual capacity that will automatically spill over to process the features of task-irrelevant singleton distractor, participants should show a significant magnitude of N2pc (i.e., attentional capture). Whereas, in the high-perceptual load condition, for the exhaustion of perceptual capacity in processing the task-relevant complex stimuli, there should be an early selection with ignoring the task-irrelevant singleton distractor and, therefore, an absence of N2pc. However, it seems unlikely that there is an absolute exhaustion of processing capacity. So, it is plausible that in certain

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 February 2025 doi:10.20944/preprints202502.1543.v1

experimental conditions, the load theory account does not always hold. Thus, if the N2pc results of our study will not fully support the predictions of PLT, by showing evidence of attentional capture under high-perceptual load or no evidence of attentional capture by task-irrelevant singleton distractor under low-perceptual load in any of the two groups of participants, then we should consider whether alternative theories such as the Signal Suppression Hypothesis (SSH) of controlled attention capture [23–28], play a role.

Numerous studies have identified distractor positivity (PD) as a lateralized posterior ERP component elicited by salient distractors. While PD shares a similar topography with the N2pc, it exhibits an opposite polarity, presenting as a contralateral positivity rather than contralateral negativity. PD typically occurs within 100 to 500 milliseconds after stimulus onset and reflects neural mechanisms involved in suppressing irrelevant or competing stimuli during tasks that demand focused attention [26,29–31]. In prior studies, when contralateral positivity appeared relatively early (e.g., 100–275 msec) before the first shift of attention (i.e., N2pc), it has been classified as early PD, providing supporting evidence for the development of the signal suppression hypothesis (SSH) of controlled attention capture [24–28,32]. According to the SSH, the salience of distractors triggers an automatic signal that, under certain conditions, can be proactively suppressed through top-down attentional control mechanisms to prevent attentional capture, particularly when distractors conflict with task goals (for reviews, see [30,33]).

Previous ERP studies promoting the SSH have considered attentional control as a process where either a distractor capture attention or is suppressed, without directly examining for the possible modulatory effect of VWM load on this process. However, Feldmann-Wüstefeld and Vogel (2019) examined the processes of enhancement and suppression during the encoding of information into VWM. Using a change detection task, participants were required to memorize certain items while ignoring others. The results showed that to-be-ignored items elicited a PD component, which increased its amplitude with salient distractor load, suggesting that the PD serves as an index of suppression efficiency [34]. According to the SSH, in the current study we hypothesize that if individuals with depressive tendencies, as compared to matched controls, have a relative deficit in top-down attentional control processes to prevent attentional capture by a task-irrelevant distractor, then the electrophysiological results should reveal a weak (or absent) early PD, followed (or replaced) by the N2pc component, which reflects the process of orienting and focusing covert attention on peripheral object features. In particular, we predict that individuals with high- as compared to the low-state depression, should not show an increased PD amplitude with increased perceptual load, in the attempt to actively suppress task-irrelevant distractor's features.

To summarize, this study evaluates the effects of loading and maintaining complex objects in VWM on distractor processing by leveraging ERP markers of selective attention. It tests the predictions of PLT, which suggests that the exhaustion of perceptual capacity in the high-perceptual load automatically reduces distractor processing (early selection), while low-perceptual load promotes bottom-up (stimulus-driven) attentional capture of a task-irrelevant distractor's features. Additionally, it considers whether the ERP findings might align better with the predictions of SSH, which suggests that if a task-irrelevant distractor's features interfere with those of the task-relevant stimuli part of the individual's active task set, then there would be the intervention of top-down (task-driven) proactive suppression mechanisms to actively suppress its features to prioritize the current task at hand. By elucidating the interplay between VWM, selective attention, and depressive symptomatology, this study contributes to a deeper understanding of cognitive dysfunction in MDD.

2. Materials and Methods

The study was approved by the local ethical committee of the University of Roehampton's School of Psychology (ethics application reference: PSYC 22/446), in accordance with the Declaration of Helsinki. All participants signed an informed consent form before their participation and received course credits or volunteered without credits for participating. Participants were fully debriefed about the purpose of the study.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 February 2025 doi:10.20944/preprints202502.1543.v1

2.1. Participants

A tool to compute statistical power analyses [35] was used to estimate a minimum sample size for the experiment of the current study. This was determined by referring to previous similar research by [19], who obtained large effect sizes, as in Experiment 1b (Cohen's d = .62). Setting the alpha level at .05 (two-tails) and a power of .80 to detect the effects of Experiment 1b [19], the suggested sample size was 23 participants. Overall, 36 volunteers naïve to the objective of the experiment participated. Of the initial sample, one volunteer was removed due to incomplete questionnaire and two were removed due to unusual low percentage of correct trials (51% and 53%) in performing the delayed match-to-sample task. Of the remaining 33 participants, whose scores on the 'Depression' subscale of the Depression Anxiety Stress Scales—21 (DASS-21; [36,37]) were below 14 (i.e., normal or mild), were classified as Low State Depression (LSD) individuals (N = 19). Those scoring 14 or above (i.e., moderate, severe or extremely severe) were classified as High State Depression (HSD) individuals (N = 14). Event related potential (ERP) and behavioral data from these two groups were analyzed. ERP studies concentrating on early P_D and N2pc generally evaluate 12 to 20 participants per subgroup, as demonstrated by an earlier investigation involving two groups with varying levels of trait anxiety [38]. Consequently, our sample size was adequate to detect variations in early P_D or N2pc between the LSD and HSD groups. The specific characteristics of the subjects in both groups are detailed in Table 1. Participants affirmed they had no medication use, history of chemical dependency, neurological issues, psychiatric/psychological disorders, or closed head injuries. There were no significant differences in age or gender between the two groups. However, the HSD group scored higher on all three subscales of the DASS-21 questionnaire compared to the LSD group.

Table 1. Demographic information of subjects with varying levels of state depression.

Group	HSD (*N* = 14)	LSD (*N* = 19)	Statistics
Age (years)	22.00 (3.35), 21.00 (18–27)	24.05 (8.10), 21.00 (19–45)	t (31) = −8.89, p = n.s.*
Gender (male, female)	4, 10	9, 10	χ^2 (1) = 1.19, p = n.s.*
Depression score	21.86 (6.35), 24.00 (14–32)	4.74 (4.18), 4.00 (0–12)	U_{Stdz} (31) = -4.87, $p < 0.001$. r= 0.85*
Anxiety score	15.00 (9.54), 15.00 (4–30)	4.21 (4.89), 2.00 (0–14)	U_{Stdz} (31) = -3.42, $p < 0.001$. r= 0.60*
Stress score	19.57 (6.98), 17.00 (8–30)	8.32 (6.26), 8.00 (0–20)	U_{Stdz} (31) = -3.63, $p < 0.001$. r= 0.63*

Values are mean (SD), median (minimum–maximum). * n.s. non-significant; t-test, chi-square test, Mann–Whitney U Standardized test, accepted at the 0.05 level of significance (2-tailed).

2.2. Self-Report Measure of State Depression

The DASS-21 is a widely administered self-report measure to assess the negative emotional states of depression anxiety and stress [37]. The DASS-21 variation of the test which is the shorter version of the 42-item questionnaire by Lovibond and Lovibond (1995) used in this study, contains 7 questions for each emotional state. This psychometric test has been proven to be reliable [39]. It displays high internal consistency with Cronbach's alpha values of 0.81, 0.89 and 0.78 for the depression anxiety and stress subscales, respectively and it has been tested for validity among both clinical and non-clinical samples [40,41]. The questionnaire assumes depression, anxiety and stress all consists of an identical nature of distress, but it also acknowledges that they have distinct individual characteristics [37]. In the case of the depression subscale, it assesses symptoms such as dysphoria, hopelessness, self-worthlessness and lack of interest. Each item is rated on a 4-point Likert scale (0 = Did not apply to me at all, 3 = Applied to me very much or most of the time). Scores are summed for each subscale and then multiplied by 2 (to align with the DASS-42 scale).

2.3. Stimuli, Experimental Procedure and Task

The Experiment was run on a PC running on a Windows operating system located in a computer room. An open-source Experiment generator software (Working Memory Analyser) programmed in Lazarus free Pascal (https://www.lazarus-ide.org) using OpenGL and Simple Direct media Layer (SDL2) libraries was used to run the visual paradigm. To promote the replicability of this study across laboratories, the software, including its experimental library of the experiment used in this study, are distributed under the GPL-3.0 license, and can be downloaded from GitHub repository (https://github.com/gfuggetta-lab/WorkingMemoryAnalyser/releases). Stimuli were presented on 24" (53.1 cm x 29.9 cm) AOC G2460PG LCD monitor with a resolution of 1920 x 1080 pixels and a refresh rate of 59.940 Hz at a viewing distance of 88 cm. To ensure accurate synchronization with millisecond precision between the onset of the visual stimuli on screen and the markers on the EEG recording system, the Trigger Station device (BrainTrends ltd https://www.braintrends.it/), was used.

For the modified delayed match-to-sample task, the monitor continuously displayed a 0.1° white fixation dot (21.5 cd/m2) in the center of an 11.84°grey circle (6.5 cd/m2), shown against a black background (see Figure 1). Four empty white rings (i.e., placeholders, 21.5 cd/m2) with an outer diameter of 1.30° and inner diameter of 1.17° (0.065° thickness) were constantly shown in the top-left, top-right, bottom-left and bottom-right quadrants on the circumference of an imaginary circle of 9.20° diameter around the central fixation dot. The visual paradigm comprised the following stimuli in sequential order: First, a foveally-presented fixation, which was a 0.78° x 0.78° grey (21.5 cd/m2) cross, appeared at the beginning of each trial for 500 ms. Second, after an interval of 500 ms, a sample array (i.e., memory set of items) comprised of four objects presented in the top-left, top-right, bottom-left and bottom-right quadrants on the circumference of an imaginary circle of 2.66° diameter around the central fixation dot was shown for 2000 ms. These four objects could be either three grey circles and one grey abstract shape (i.e. low VWM capacity load 1), or four grey abstract shapes (i.e. high VWM capacity load 4). All objects had a size of 0.84°. In terms of non-nameable abstract shapes, the following sixteen stimuli (

and  were used as well as their 180º rotated clockwise copies for a total of 32 abstract shapes. These abstract shapes were generated according to method 1 of [42] as in previous studies [43,44]. Third, after an interval of 800 ms, a task-irrelevant singleton distractor array (i.e., prime display) was shown for 200 ms. The distractor singleton was always a task-irrelevant Chinese character (not part of the current task-set). The following sixteen Chinese characters (么, 子, 也, 手, 亡, 刃, 久, 分, 女, 止, 示, 尤, 反, 牙, 云, and 勿) selected from the set A and set B of targets of the Shum Visual Learning Test [45] were shown as well as their 180º rotated clockwise copies for a total of 32 characters. Eadie and Shum (1995) demonstrated that non-Chinese speakers do not easily verbalize Chinese characters. They developed a test of visual learning based on the set of Chinese characters with the lowest scores on verbalizability and provided evidence for its construct validity [46]. The task-irrelevant Chinese characters appeared within one of the four placeholders' positions among fifteen non-target homogenous 0.84° diameter grey circles, spaced evenly on the circumference of an imaginary circle of 9.20° diameter around the central fixation dot. All shapes were isoluminant (30.4 cd/m2). Fourth, after an interval of 800 ms, a memory probe with an abstract shape (i.e., target) which appeared within one of four placeholders' positions was shown for 500 ms. This limited visual search to the four positions needed to perform the modified delayed match-to-sample task. Thus, the 4 distractor positions appeared an equal number of times per trials and were fully counterbalanced with the 4 target locations, making the target position unpredictable. Using a block design, in each of the 8 blocks of 64 trials, the singleton distractor object not part of the task set, being a Chinese character. Fifth, after a response time interval of 1800 ms, visual feedback of 2.07° with either a green happy face () for correct responses or a red sad face () for incorrect

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 February 2025 doi:10.20944/preprints202502.1543.v1

responses or omissions in front of the fixation dot at the center of the screen was shown for 200 ms, followed by a fixed duration of 300 ms before the next trial began.

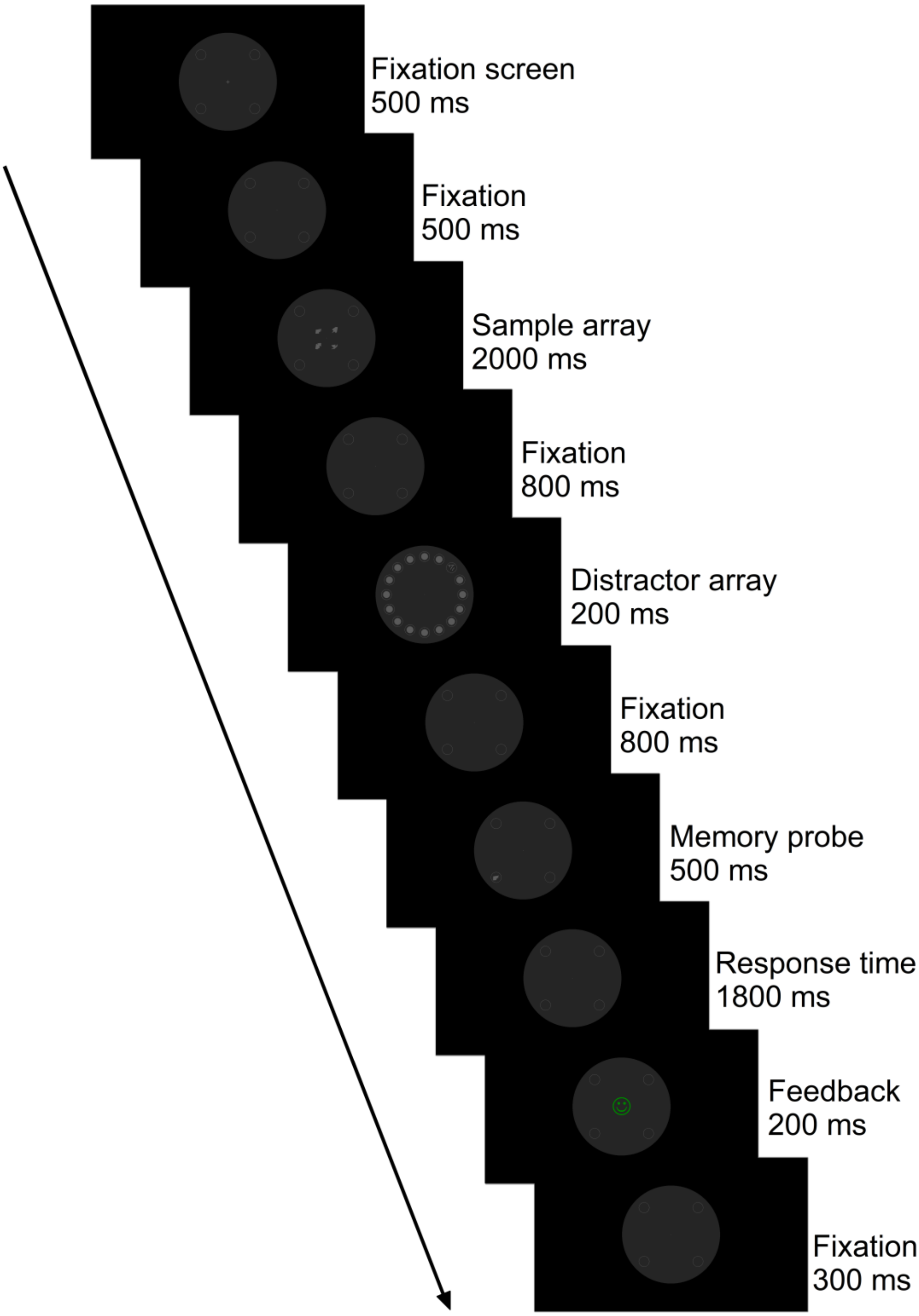


Figure 1. Example of the stimuli of a trial of the modified delayed match-to-sample task. Each trial began with presentation of fixation cross, followed by a sample array (i.e., memory set). A distractor array was interleaved during the retention interval showing a task-irrelevant 'singleton' item. The singleton was a Chinese character not part of the current task set. The trial ended with a memory probe (i.e., target) followed by a response time interval and visual feedback. Participants were asked to hold the memory set in mind during the retention interval and decide whether the memory probe was matching or mismatching any of the items presented as part of the sample array (i.e., match-to-sample task). They were also instructed to ignore the distractor array and fixate central fixation dot throughout the experiment. This trial is an example of high-visual working memory (VWM) capacity load (i.e., four abstract shapes are encoded in VWM) with a Chinese character as distractor

singleton and, spatially incompatible distractor-to-memory probe position (i.e., the distractor singleton appeared on the top-right quadrant and the memory probe appeared on the bottom-left quadrant). This is an example of a match memory probe-to-sample task trial (i.e., the abstract shape shown as memory probe matches one of the abstract shapes presented as part of the sample array). Stimuli are drawn to scale.

Participants were presented the instructions of delayed match-to-sample task in auditory and visual modalities prior to performing the training trials of the visual paradigm. Thus, a pre-recorded audio file in Mp3 format was played (see supplementary material) and a picture in bitmap format was shown on screen alongside the audio instructions given by an AI generated voice to ensure consistency in delivering the instructions across participants and that participants understood the requirements of the task, including which buttons to press using a response box (see Appendix A). Participants were explicitly instructed to fixate central fixation dot throughout the experiment, memorize the initial sample array, ignore the distractor array and respond only to the memory probe. The participants' task was to indicate using the left and right buttons of a response box whether the abstract shape, as part of the memory probe, was the same or different from the abstract shape(s) shown as part of the sample array (i.e. delayed match-to-sample task) in either a low VWM capacity load (1) or high VWM capacity load (4) conditions. The singleton stimulus as part of the distractor array was consistently a Chinese character, not part of the current task set. Importantly, the task-irrelevant Chinese character appeared as a single pop-out item among a homogeneous array of 15 grey circles across all conditions requiring a singleton detection mode, and none of the distractor arrays were altered between VWM load conditions (i.e., they were perceptually identical), preventing any dilution of the salient distractor item. In the experiment, we therefore manipulated perceptual load, whilst maintaining a singleton detection attentional set. The distractor singleton as Chinese character was lateralized and could appear unpredictably in one of four possible quadrants on screen either in a compatible (25% of valid trials) (i.e. spatial ignored repetition), or incompatible (75% of invalid trials) spatial position as compared to the incoming lateralized target location, which also appeared unpredictably in one of four quadrants. Thus, in only 25% of trials, the spatial position of the distractor singleton in the prime display became the target's spatial position in the subsequent probe display. These experimental manipulations could lead to either Spatial Negative Priming (SNP) or Spatial Positive Priming (SPP) effects [47,48]. SNP/SPP represent a inhibitory/faciliatory effect that occurs when shifting attention towards a perceived distractor's spatial position on a prime display, with a subsequent re-orientation of spatial attention, results in slower/faster and less/more accurate target detection when it appears at the same distractor stimulus' spatial location as compared to elsewhere, due to the residual inhibition/facilitation being deployed to that location [47,48]. To keep the target as a single onset stimulus, but clearly demarcate the distractor as a task-irrelevant singleton as part of the distractor array, we presented this singleton distractor (i.e., prime display) in a fixed temporal order of 1000 ms prior to target onset (i.e., probe display); sufficient time to disengage from the distractor [49]. Unlike many previous manipulations of perceptual capacity using VWM load which require a dual-task design (e.g., [19,50,51], the current design was a single-task and therefore mitigated any additional cognitive load from maintaining multiple task rules in mind. Before the main part of the experiment, participants completed 20 practice trials to familiarize themselves with the task and adjust to the requirements. These practice trials were repeated until the average accuracy was greater than 60%. Participants completed 512 trials in eight blocks of 64 trials and were allowed to pause in between blocks. The experiment had the following Experimental conditions: 1) VWM capacity load, with two levels of randomly distributed trials: low (256 trials) vs. high (256 trials); 2) distractor-to-memory probe spatial compatibility, where each level of VWM capacity loads had four levels of randomly distributed distractor-to-memory probe horizontal and vertical spatial compatibilities: horizontally compatible and vertical compatible (64 trials) vs. horizontally compatible and vertical incompatible (64 trials); horizontally incompatible and vertical compatible (64 trials); horizontally incompatible and vertical incompatible (64 trials). The distractor-to-memory probe spatial compatibility effects indicate the extent to which participants' selective attention was biased by the singleton distractor's features on direct electrophysiological measures and indirect behavioral measures in performing the modified delayed match-to-sample abstract shape task. Speed and accuracy were encouraged. The number of trials where the memory probe was matching or mismatching from any of the items presented as part of the sample array was balanced across each combination of the eight experimental conditions: VWM capacity load (low 1, and high 4), horizontal spatial compatibility (incompatible, and compatible) and vertical spatial compatibility (incompatible, and compatible). Half of the trials within each experimental condition required same probe-to-sample response. Whereas the remining half of the trials required different probe-to-sample response. The response button mapping (i.e., left button when the memory probe was different from the sample and right button when the memory probe was the same as the sample or vice versa) was randomized across participants.

2.3. Electrophysiological Data

2.3.1. General Pre-Processing of Electrophysiological Data

Using the 64-channel Biosemi ActiveTwo EEG system (BioSemi, Amsterdam, Netherlands), continuous EEG data was recorded through a quickcap adhering to the 10/10 system at a sampling rate of 2048 Hz. Flat-type electrodes were positioned 1cm from the outer canthi of both eyes to capture horizontal electrooculograms (HEOG). For vertical electrooculograms (VEOG) and blinks, electrodes were placed above and below the right eye. Additionally, two electrodes were attached to each earlobe. Pin-type electrodes were secured with an elastic cap after applying electrode gel. Unlike other EEG systems, the ActiveTwo allows for reference-free EEG signal recording. Instead, the ground reference is managed by two electrodes (DRL/CMS) creating a feedback loop to regulate the current from the participant to the analogue digital (AD) box.

EEG data pre-processing was conducted with BrainVision Analyzer 2.3 software (Brain Products GmbH). First, three channels that did not containing data for further analysis have been disabled (EXG7, EXG8 and Status). Next, a linear derivation function was applied to compute a bipolar HEOG channel from outer canthi electrodes of both eyes (i.e., HEOGL and HEOGR) and a VEOG channel using the two electrodes placed above and one below the right eye (i.e., VEOGU and VEOGL). Next, raw EEG data were band-pass filtered between 0.3 and 46 Hz with 8th order rolloffs with a 50 Hz notch employing a zero-phase shift Butterworth (IIR) filters. Next, an automatic raw data inspection was conducted excluding frontal electrodes that were contaminated by eye movements and blinks (i.e., Fp1, AF7, AF3, F7, F5, F3, F1, FPz, AFz, Fz, Fp2, AF8, AF4, F8, F6, F4, F2). The EEG events were marked as bad from 200 ms before to 200 ms after the event by applying the following exclusion criteria: 1) check gradient, if the maximal allowed voltage step was exceeding 50 μV/ms; 2) check difference (Max-Min), if the values in 200 ms intervals exceed 200 μV; 3) check amplitude, if the minimal and maximal allowed amplitude exceeded ± 200 μV; 4) check low activity, if the values in 100 ms intervals was lower than 0.5 μV). Next, if EEG channels contained intervals with obvious non-ocular artifacts (i.e., muscular contractions and electrode artefacts) over prolonged periods (i.e. > 100 seconds), these were removed. Next, after the exclusion of bad channels, the automatic raw data inspection procedure was re-conducted on the remaining "good" channels to reduce the amount of EEG intervals marked as bad and, therefore, maximize the amount of EEG signal to use in the subsequent pre-processing stages. Next, as a pre-processing step for ICA ocular artifact reduction procure, high-pass filtering at 1 Hz (8th order rolloffs) zero-phase shift Butterworth (IIR) filter was applied to compute the ICA weights and produce good results in terms of signal-to-noise ratio (SNR) [52]. Next, ocular artifacts were reduced by employing the ICA function within the BrainVision Analyzer software using VEOG/HEOG channels. This function searches for an ocular artifact template in VEOG/HEOG channels and then finds ICA-derived components that account for a user specified amount of variance (70%) in the template matched portion of the signal from VEOG/HEOG. Data used for ICA was 328 seconds long and the ICA algorithm used was Infomax Restricted. Next, ICA weights to less high-pass filtered data (i.e., 0.3 Hz, 8th order rolloffs) were applied using a linear derivation function. So, the ICA components containing artefacts were removed from the EEG signal

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 February 2025 doi:10.20944/preprints202502.1543.v1

which was then reconstructed for further processing. Next, bad EEG channels that were previously removed, were topographically spline interpolated with order 4, degree 10 and lambda 1E-05. Next, the original order of the 64 electrodes plus A1, A2, HEOG and VEOG was re-established. Next, the EEG data was re-referenced to the average of earlobe electrodes (A1 and A2). Next, the sampling rate down-sampled to 1000 Hz based on spline interpolation. Next, in the case of ERPs at distractor singleton array onset, continuous EEG data was epoched from -1500 ms to +1501 ms and baseline corrected with 200 ms period before distractor array onset. Next, an artifact rejection - automatic inspection function was applied three times. Epochs in the time interval from -200 ms to 350 ms post distractor singleton onset with eye blinks (exceeding ±60 µV at FP1, FPz, and FP2 channels), eye-movements (exceeding ±30 µV in the HEOG channels), and movement-related artifacts (exceeding ±80 µV in all other channels) were rejected.

3.3.2. Analysis of Event-Related Potentials

Artefact-free epochs were used to compute separate average ERPs for lateral parieto-occipital electrodes. To isolate the magnitude of the P_D and N2pc components elicited by the singleton distractor array, at lateral occipital PO7/8 electrodes, we computed difference waves by subtracting ipsilateral from contralateral electrodes relative to the singleton distractor location. To eliminate any hemispheric asymmetries that were unrelated to attention, we averaged the difference waves across left- and right-hemispheres. At post-distractor array onset, the mean amplitude measures of lateralized ERP components were extracted from a time window between 170 and 230 ms for early P_D and between 273 and 293 ms for N2pc at PO7/8 electrodes site.

2.4. Statistical Analysis

In the case of statistical analysis of electrophysiological data at distractor array onset, the mean amplitude of lateralized early P_D and N2pc, were submitted to mixed ANOVAs which had a between subjects' factor of state depression group (low and high) and a within subjects' factor of VWM capacity load (low 1 and high 4). To evaluate the presence of a significant magnitude of early P_D and N2pc components for each of the two-state depression groups at different levels of VWM capacity load, one-sample t-tests with test value 0 were also conducted. In terms of behavioral data, after removing omissions and response times less than 200 ms and above 2100 ms, the mean accuracy (%) and mean correct response times (RTs; ms) in performing the task were analyzed. Mean accuracy (%) and mean correct RTs (ms) were subjected to a 4-ways mixed design ANOVAs with a between subjects' factor of state depression group (low and high) and three within subjects' factors of VWM capacity load (low 1 and high 4), distractor-to-memory probe horizontal spatial compatibility (compatible and incompatible); and distractor-to-memory probe vertical spatial compatibility (compatible and incompatible). In all repeated measures ANOVAs for lateralized ERPs, and behavioral data, Greenhouse–Geisser epsilon adjustments for non-sphericity were applied where appropriate. Post-hoc pairwise comparisons of the means were conducted using the Bonferroni method unless differently specified. For all statistical tests, p <0.05 (2-tailed) was considered significant.

3. Results

3.1. Electrophysiological Results

Statistical analyses on mean amplitude (±SEM) of early P_D, with an overall amplitude of .28 (± .07) µV, revealed a non-significant main effect of VWM capacity load, with $F_{(1, 31)} = 1.11$, $p = .30$, ηp2= .03 or interaction between VWM capacity load with state depression group, with $F_{(1, 31)} = 1.31$, $p = .26$, ηp2= .04. Crucially, there was a significant main effect of state depression group, with $F_{(1, 31)} = 9.05$, $p < .01$, ηp2= .23. The mean amplitude of the early P_D was of .07 (± .11) µV in the case of HSD group and of .49 (± .09) µV, for the LSD group. One-sample t-tests with test value 0, revealed that in the case of HSD individuals, the magnitude of early P_D did not reach statistical significance at both levels of VWM capacity load: low load (1) .07 (± .18) µV, with $t_{(13)} = .42$, p =.68; and high load (4) .06 (± .13) µV, with $t_{(13)}$ = .47, p =.64. Whereas in the case of LSD individuals, there was a significant magnitude of early P_D at both levels of VWM capacity load: low load (1) .35 (± .12) µV, with $t_{(18)}$ = 2.95, p <.01; and high load (4) .62 (± .11) µV, with $t_{(18)}$ = 5.87, p <.001. Statistical analyses on mean amplitude (±SEM) of N2pc, with an overall amplitude of -.23 (± .11) µV, revealed a non-significant main effect of VWM capacity load, with $F_{(1, 31)}$ = 2.14, p = .15, ηp2= .06 or interaction between VWM capacity load with state depression group, with $F_{(1, 31)}$ = .84, p = .36, ηp2= .03. Lastly, the main effect of state depression group, was not significant with $F_{(1, 31)}$ = 1.96, p =.17, ηp2= .06. The mean amplitude of N2pc was -.38 (± .17) µV in the case of HSD group and of -.07 (± .14) µV, for the LSD group. One-sample t-tests with test value 0, revealed that in the case of HSD individuals, in the low VWM capacity load (1) condition, there was a significant magnitude of N2pc of -.42 (± 0.19) µV, with $t_{(13)}$ = -2.21, p <.05. However, in the high VWM capacity load (4), the magnitude of N2pc of -.33 (± .19) µV did not reach statistical significance, with $t_{(13)}$ = -1.76, p =.10. In the case of LSD individuals, the magnitude of N2pc was of -.27 (± .19) µV at low (1) and of -.12 (± .19) µV at high (4) VWM capacity load conditions and did not reach statistical significance, with $t_{(18)}$ = -1.44, p =.17; and $t_{(18)}$ = .64, p =.53, respectively. The grand averages of lateralized early P_D and N2pc at PO7/8 electrodes comparing the two groups of participants for low- and high-VWM loads are shown in Figure 2.

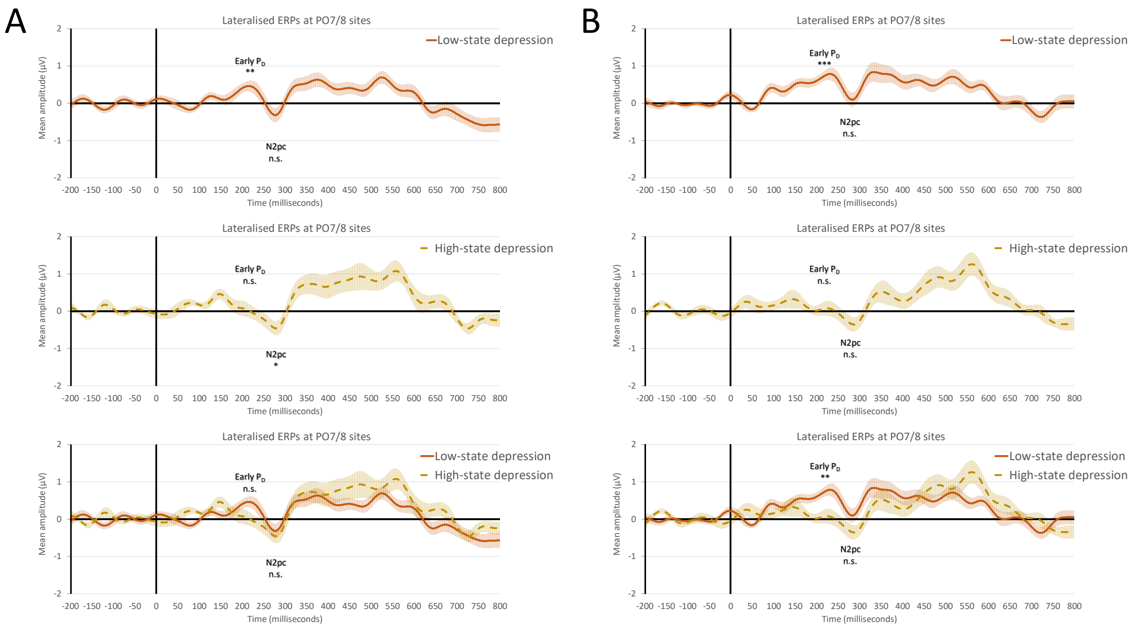


Figure 2. Grand averages of lateralized early P_D and N2pc ERP components at parieto-occipital PO7/8 electrode sites from distractor array onset comparing low-state depression (LSD) and high-state depression (HSD) groups. (A) Lateralized ERPs at low-visual working memory capacity load (i.e., one abstract shape encoded in VWM); (B) Lateralized ERPs at high-visual working memory capacity load (i.e., four abstract shapes encoded in VWM). Overall, LSD individuals successfully suppressed the singleton distractor, showing early P_D and absence of N2pc. In contrast, HSD participants demonstrated to have an impairment of top-down proactive control of features gain to prevent attentional capture by the task-irrelevant singleton distractor, showing an absence of early P_D and presence of N2pc in the low VWM load condition. n.s. denotes a non-significant difference. Whereas *, ** and *** indicate a significant difference with p <.05, p <.01 and p <.001, respectively. Error bars represent (±SEM).

3.2. Behavioral Results

The overall mean accuracy (±SEM) in performing the modified delayed match-to-sample task was 76.00 (± 1.65) %. There was a significant main effect of VWM capacity load, with $F_{(1,31)}$ = 201.31, p <.001. ηp2=.87. The accuracy in performing the task was significantly reduced at low- (1) as compared to high- (4) VWM load (87.83 vs. 64.17%). There was a significant 2-way interaction VWM load x state

 doi:10.20944/preprints202502.1543.v1

depression group, with $F_{(1,31)} = 4.23$, $p <.05$. ηp2=.12. Post-hoc pairwise comparisons revealed that this significant interaction was driven by the VWM experimental manipulation rather than by the individual differences in state depression. Indeed, in the case of HSD group, there was a reduction in accuracy comparing low- and high- VWM loads (89.04 vs. 61.95%, $p <.001$). A similar VWM load effect was found for LSD individuals (86.61 vs. 66.38%, $p <.001$. However, the mean accuracy in performing the task did not differ significantly comparing the HSD with LSD group at low- (89.04 vs. 86.61 %, $p =.53$) and high- (61.95vs. 66.38%, $p =.24$) VWM load, respectively. There was also a significant 2-way interaction VWM load x distractor to target vertical spatial compatibility, with $F_{(1, 31)} = 4.27$, $p <.05$. ηp2=.12. However, post-hoc pairwise comparisons did not reveal a significant difference comparing vertical spatially compatible with vertical spatially incompatible distractor-to-memory probe conditions at both low- (87.13 vs. 88.52%, $p =.06$) and high- VWM loads (64.81 vs. 63.52%, $p =.19$). No other main effects or interactions were statistically significant. The overall mean correct response time (±SEM) in performing the voluntary task was 928.39 (± 35.86) ms. There was a significant main effect of VWM capacity load, with $F_{(1,31)} = 82.40$, $p <.001$. ηp2=.73, revealing significantly faster responses at low- (1) as compared to high- (4) VWM load (851.70 vs. 1005.08 ms). There was a significant main effect of distractor to target horizontal spatial compatibility, with $F_{(1, 31)} = 5.27$, $p <.05$. ηp2=.15. Mean correct response time was significantly faster for same as compared to different distractor to target horizontal position (922.41 vs. 934.37 ms) suggesting the presence of a spatial positive priming (SPP) effect. No other main effects or interactions were statistically significant. In particular, there was not a significant difference in mean correct responses comparing the HSD with LSD groups at low- (837.99 vs. 865.40 ms, $p =.73$) and high- (976.38 vs. 1033.78 ms, $p =.42$) VWM loads.

4. Discussion

This electrophysiological study aimed at investigating if individuals experiencing high-state depression, exhibit weakened top-down attentional control processes, especially feature-based selective attention. Two groups of participants with different levels of state depression, as evaluated with the DASS-21 [36,37], performed a modified version of a delayed match-to-sample task [9], which required to ignore a task-irrelevant singleton distractor as part of a distractor array under low- and high-VWM capacity loads.

The first ERP component evaluated at distractor array onset was the early P_D, which is thought to measure a process associated with proactive attentional suppression that is applied to salient distractors to prevent attentional capture [27,29,33]. Whereas, the second ERP component under scrutiny was the N2pc, which reflects the process of orienting and focusing covert attention on peripheral stimulus features and indicative of attentional capture [14–17].

Two main theories have been considered in examining the ERP results of the current study. The PLT [10,11,22], assumes that the early selection process of task-irrelevant distractors is governed by an automatic mechanism (i.e., if perceptual capacity is exhausted in processing a large amount of relevant information, then no attentional resources for perceiving irrelevant stimuli are left). Thus, according to the PLT, in the high- (vs. low) perceptual load condition, due to perceptual capacity exhaustion, there should be ERP evidence of an automatic rejection of the distractor with absence of both early P_D and N2pc components. On the contrary, according to the SSH of controlled attentional capture [25–27], in the high- (vs. low) perceptual load condition, with the intervention of top-down attentional control mechanisms, there should be ERP evidence of a proactive suppression of task-irrelevant distractor features with and enhanced amplitude of early P_D and absence N2pc components to promote the performance of the current task at hand in face of distraction.

The ERP results highlight distinct patterns in early P_D and N2pc amplitudes between state depression groups and under varying perceptual loads. The individuals belonging to the LSD group, demonstrated to have a significant magnitude of early P_D for both low- and high- VWM capacity loads. These findings for the LSD individuals are supporting the predictions of the SSH of controlled attention capture, revealing that salient stimuli elicit a bottom-up ‘attend to me’ signal, which under some task conditions, such as when they are incongruent with the current attentional set, can be successfully suppressed (see review by [33]). Interestingly, LSD individuals exhibited an overall significantly larger early P_D amplitude as compared to HSD individuals. Crucially, there was no evidence of early P_D for either low- or high-VWM capacity loads in the HSD group. Overall, these findings are supporting the main hypothesis of this study, suggesting that individuals exhibiting high levels of depressive symptoms have an impairment in the top-down mechanism of proactive control of feature gain, a cognitive strategy that involves maintaining goal-relevant information before a task-irrelevant stimulus biases attention and perception [53].

In the current study, the reduced negativity for contralateral (vs ipsilateral) singletons, has been associated to the early P_D, a measure proactive attentional distractor suppression (See for review [33]). However, in the experiment the distractor array has a unilateral singleton distractor. Thus, it may be the case that the presence of an early lateralized waveform could instead be the *positivity posterior contralateral* (Ppc) component, which may be related with a sensory low-level imbalance in the physical structure of search displays by presenting a feature singleton in one hemifield but not the other [54–56] but also initial activation on salience maps with a generalized salience signal [55,57–59]. Crucially, the results of the early lateralized positive component in the current study, confirm that it was indeed the early P_D, rather than the Ppc, because the low-level imbalance of distractor array, was identical in both groups of participants regardless of their differences of state depression. Thus, the only remaining explanation why the LSD group only has shown a significant early effect of reduced negativity for contralateral (vs ipsilateral) singletons in both low- and high VWM loads, is for the efficiency of top-down mechanism operating to actively suppress the singleton distractor in this group as compared to the HSD group.

To complement the findings of the early P_D, the distractor was found to trigger an N2pc in the HSD group but not in the LSD group under low-perceptual load condition. These findings suggest that individuals exhibiting high levels of depressive symptoms, oriented and focused covert attention on the peripheral task-irrelevant stimulus features. Therefore, HSD participants, for their relative deficits in top-down attentional control mechanisms, have not successfully prevented the stimulus-driven attention capture towards the singleton distractor features which were not part of the current attentional set, as compared to their LSD counterparts. Interestingly, individuals with higher depression states did not show a significant magnitude of N2pc in the high-perceptual load condition, suggesting an absence of attentional bias towards the task-irrelevant distractor's features when VWM was strained. Overall, the N2pc findings for the HSD group, demonstrate the influence of perceptual load on distractor processing, consistent with the predictions of the PLT [10,11]. PLT posits that perception is an automatic process that is dependent on limited perceptual capacity. Consequently, when perceptual load is low (e.g., encoding one complex object in VWM), surplus capacity allows for the processing of irrelevant stimuli (i.e., Chinese character's shape). However, when perceptual load is high (e.g., encoding four complex objects in VWM), attentional capacity is depleted, effectively preventing distractor processing.

Contrary to the direct electrophysiological findings of the current study, our behavioral data did not support the hypothesis that HSD individuals have an impairment of attentional control by hindering the suppression of attentional capture by irrelevant stimuli. We propose that individuals experiencing high levels of depressive symptoms may compensate for potential top-down attentional control deficits by allocating more attentional resources to the primary match-to-sample task, enabling them to perform as well as individuals with LSD. This compensatory mechanism has been suggested in previous research, which observed impaired executive control in individuals with high anxiety levels, highlighting the potential limitations of relying solely on behavioral performance measures to identify specific attentional deficits [38,60]. The main behavior finding of the current study was that regardless of state depression, correct response times in performing match-to-sample task were significantly faster for same (compatible) as compared to different (incompatible) distractor to target horizontal position, which is suggesting the presence of a spatial positive priming (SPP) effect [47]. Thus, it seems that participants' visual-spatial attention was somewhat drawn to the singleton distractor on the prime display. This led to faster target detection when it appeared in the same location as the distractor, presumably due to residual attentional activation at that location.

 doi:10.20944/preprints202502.1543.v1

Overall, the electrophysiological results of the current investigation suggest that state depressed individuals have an impairment in top-down attentional control and in particular in feature-based selective attention as it has been previously documented in MDD [1,4]. This impairment makes it challenging for them to filter out irrelevant, distracting information, potentially hindering their ability to maintain focus on goal-oriented tasks and contributing to the cognitive difficulties linked to depression. In terms of the implications of the findings of this study and future research directions, the modified delayed match-to-sample task may be used in clinical applied research to evaluate the efficacy of targeted training programs developed to strengthen attentional control and selective attention mechanisms in individuals with depression. Alternatively, it can be used as part of attention-based cognitive training tools designed to help individuals filter out irrelevant stimuli and enhance their ability to focus on goal-relevant information. This can be particularly useful in educational settings or workplace environments, where distractions impair performance, and in clinical treatments for depression to reduce cognitive interference and improve daily functioning.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org.

Author Contributions: Conceptualization, G.F.; methodology, G.F.; software, G.F. and P.D.; formal analysis, G.F.; investigation, G.F., R.C., P.M., J.C., and E.D.; resources, G.F.; data curation, G.F., and R.C.; writing—original draft preparation, G.F.; writing—review and editing, G.F.; visualization, G.F.; supervision, G.F.; project administration, G.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Ethics Committee of University of Roehampton (Ethics Application reference code: PSYC 22/ 446. Date of approval: 06 February 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Acknowledgments: Giorgio Fuggetta wishes to thank Dmitry Boyarintsev for his support in programming the software Working Memory Analyser (WMA) for Windows and MacOS using Lazarus, the professional Free pascal cross-platform Integrated Development Environment (IDE) for Rapid Application Development (RAD) https://www.lazarus-ide.org/. William Hawken, for technical support. This research is dedicated to the memory of Enea Francesco Pavone (1972-2018), Howard David Page-Clark (1953-2023) and my loving mother-in-law, Sadhana 'Bani' Purkayastha (1945-2024).

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

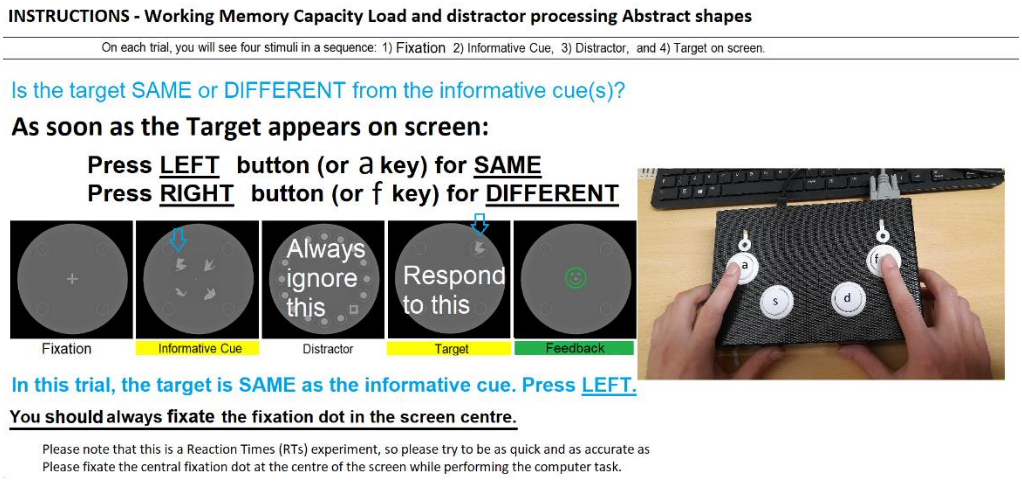
The following abbreviations are used in this manuscript:

MDD	Major Depressive Disorder
DASS	Depression Anxiety Stress Scales
VWM	Visual Working Memory
ERP	Event-related potential
P_D	distractor positivity
PLT	Perceptual Load Theory
SSH	Signal Suppression Hypothesis
LSD	Low State Depression
HSD	High State Depression
MEG	magnetoencephalographic
SNP	Spatial Negative Priming
SPP	Spatial Positive Priming

Appendix A

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 February 2025 doi:10.20944/preprints202502.1543.v1

Participants received visual instructions for the delayed match-to-sample task while listening to a pre-recorded audio file in MP3 format containing the instructions delivered by an AI voice.



References

1. Keller, A.S., et al., *Paying attention to attention in depression.* Translational Psychiatry, 2019. **9**(1): p. 279.
2. Katsuki, F. and C. Constantinidis, Bottom-Up and Top-Down Attention:Different Processes and Overlapping Neural Systems. The Neuroscientist, 2014. **20**(5): p. 509-521.
3. Nobre, A.C. and S. Kastner, *1201Attention: Time Capsule 2013*, in *The Oxford Handbook of Attention*, A.C. Nobre and S. Kastner, Editors. 2014, Oxford University Press. p. 0.
4. Keller, A.S., T.M. Ball, and L.M. Williams, Deep phenotyping of attention impairments and the 'Inattention Biotype' in Major Depressive Disorder. Psychological Medicine, 2020. **50**(13): p. 2203-2212.
5. Ladouceur, C.D., et al., *Altered error-related brain activity in youth with major depression.* Developmental Cognitive Neuroscience, 2012. **2**(3): p. 351-362.
6. Olvet, D.M., D.N. Klein, and G. Hajcak, *Depression symptom severity and error-related brain activity.* Psychiatry Research, 2010. **179**(1): p. 30-37.
7. Luck, S.J. and E.K. Vogel, The capacity of visual working memory for features and conjunctions. Nature, 1997. **390**(6657): p. 279-281.
8. Luck, S.J. and E.K. Vogel, Visual working memory capacity: from psychophysics and neurobiology to individual differences. Trends in Cognitive Sciences, 2013. **17**(8): p. 391-400.
9. Fuggetta, G. and P.A. Duke, Enhancing links between visual short term memory, visual attention and cognitive control processes through practice: An electrophysiological insight. Biological Psychology, 2017. **126**: p. 48-60.
10. Lavie, N., *Perceptual load as a necessary condition for selective attention.* Journal of Experimental Psychology: Human Perception and Performance, 1995. **21**(3): p. 451-468.
11. Lavie, N. and Y. Tsal, Perceptual load as a major determinant of the locus of selection in visual attention. Perception & Psychophysics, 1994. **56**(2): p. 183-197.
12. Lavie, N. and E. Fox, *The role of perceptual load in negative priming.* Journal of Experimental Psychology: Human Perception and Performance, 2000. **26**(3): p. 1038-1052.
13. Brockhoff, L., S. Schindler, M. Bruchmann, and T. Straube, Effects of perceptual and working memory load on brain responses to task-irrelevant stimuli: Review and implications for future research. Neuroscience & Biobehavioral Reviews, 2022. **135**: p. 104580.
14. Drisdelle, B.L. and M. Eimer, PD components and distractor inhibition in visual search: New evidence for the signal suppression hypothesis. Psychophysiology, 2021. **58**(9): p. e13878.
15. Luck, S.J., Electrophysiological correlates of the focusing of attention within complex visual scenes: N2pc and related ERP components, in The Oxford handbook of event-related potential components. 2012, Oxford University Press: New York, NY, US. p. 329-360.
16. Luck, S.J. and S.A. Hillyard, *Spatial filtering during visual search: Evidence from human electrophysiology.* Journal of Experimental Psychology: Human Perception and Performance, 1994. **20**: p. 1000-1014.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 February 2025 doi:10.20944/preprints202502.1543.v1

17. Luck, S.J. and S.A. Hillyard, *Electrophysiological correlates of feature analysis during visual search.* Psychophysiology, 1994. **31**(3): p. 291-308.
18. Hopf, J.-M., et al., *Neural Sources of Focused Attention in Visual Search.* Cerebral Cortex, 2000. **10**(12): p. 1233-1241.
19. Konstantinou, N. and N. Lavie, *Dissociable roles of different types of working memory load in visual detection.* Journal of Experimental Psychology: Human Perception and Performance, 2013. **39**: p. 919-924.
20. Lavie, N., *Distracted and confused?: Selective attention under load.* Trends in Cognitive Sciences, 2005. **9**(2): p. 75-82.
21. Lavie, N. and S. Cox, On the Efficiency of Visual Selective Attention: Efficient Visual Search Leads to Inefficient Distractor Rejection. Psychological Science, 1997. **8**(5): p. 395-396.
22. Lavie, N. and P. Dalton, *56Load Theory of Attention and Cognitive Control*, in *The Oxford Handbook of Attention*, A.C. Nobre and S. Kastner, Editors. 2014, Oxford University Press. p. 0.
23. Gaspelin, N., C.J. Leonard, and S.J. Luck, *Direct Evidence for Active Suppression of Salient-but-Irrelevant Sensory Inputs.* Psychological Science, 2015. **26**(11): p. 1740-1750.
24. Gaspelin, N., C.J. Leonard, and S.J. Luck, *Suppression of overt attentional capture by salient-but-irrelevant color singletons.* Attention, Perception, & Psychophysics, 2017. **79**(1): p. 45-62.
25. Gaspelin, N. and S.J. Luck, *The Role of Inhibition in Avoiding Distraction by Salient Stimuli.* Trends in Cognitive Sciences, 2018. **22**(1): p. 79-92.
26. Gaspelin, N. and S.J. Luck, Combined Electrophysiological and Behavioral Evidence for the Suppression of Salient Distractors. Journal of Cognitive Neuroscience, 2018. **30**(9): p. 1265-1280.
27. Sawaki, R. and S.J. Luck, Capture versus suppression of attention by salient singletons: Electrophysiological evidence for an automatic attend-to-me signal. Attention, Perception, & Psychophysics, 2010. **72**(6): p. 1455-1470.
28. Vatterott, D.B. and S.P. Vecera, *Experience-dependent attentional tuning of distractor rejection.* Psychonomic Bulletin & Review, 2012. **19**(5): p. 871-878.
29. Hickey, C., V. Di Lollo, and J.J. McDonald, *Electrophysiological Indices of Target and Distractor Processing in Visual Search.* Journal of Cognitive Neuroscience, 2009. **21**(4): p. 760-775.
30. Luck, S.J., et al., Progress Toward Resolving the Attentional Capture Debate. Vis cogn, 2021. **29**(1): p. 1-21.
31. Sawaki, R. and S.J. Luck, Active suppression of distractors that match the contents of visual working memory. Visual Cognition, 2011. **19**(7): p. 956-972.
32. Ipata, A.E., et al., LIP responses to a popout stimulus are reduced if it is overtly ignored. Nature Neuroscience, 2006. **9**(8): p. 1071-1076.
33. Gaspelin, N., et al., *The Distractor Positivity Component and the Inhibition of Distracting Stimuli.* Journal of Cognitive Neuroscience, 2023. **35**(11): p. 1693-1715.
34. Feldmann-Wüstefeld, T. and E.K. Vogel, Neural Evidence for the Contribution of Active Suppression During Working Memory Filtering. Cerebral Cortex, 2018. **29**(2): p. 529-543.
35. Faul, F., E. Erdfelder, A.G. Lang, and A. Buchner, G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods, 2007. **39**(2): p. 175-91.
36. Lovibond, P.F. and S.H. Lovibond, The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. Behaviour Research and Therapy, 1995. **33**(3): p. 335-343.
37. Zanon, C., et al., Examining the Dimensionality, Reliability, and Invariance of the Depression, Anxiety, and Stress Scale–21 (DASS-21) Across Eight Countries. Assessment, 2021. **28**(6): p. 1531-1544.
38. Gaspar, J.M. and J.J. McDonald, *High Level of Trait Anxiety Leads to Salience-Driven Distraction and Compensation.* Psychological Science, 2018. **29**(12): p. 2020-2030.
39. Osman, A., et al., The Depression Anxiety Stress Scales—21 (DASS-21): Further Examination of Dimensions, Scale Reliability, and Correlates. Journal of Clinical Psychology, 2012. **68**(12): p. 1322-1338.
40. Clara, I.P., B.J. Cox, and M.W. Enns, *Confirmatory Factor Analysis of the Depression–Anxiety–Stress Scales in Depressed and Anxious Patients.* Journal of Psychopathology and Behavioral Assessment, 2001. **23**(1): p. 61-67.

41. Sinclair, S.J., et al., Psychometric Evaluation and Normative Data for the Depression, Anxiety, and Stress Scales-21 (DASS-21) in a Nonclinical Sample of U.S. Adults. Evaluation & the Health Professions, 2012. **35**(3): p. 259-279.
42. Attneave, F. and M.D. Arnoult, *The quantitative study of shape and pattern perception.* Psychological Bulletin, 1956. **53**: p. 452-471.
43. Hautzel, H., et al., Evidence of a modality-dependent role of the cerebellum in working memory? An fMRI study comparing verbal and abstract n-back tasks. NeuroImage, 2009. **47**(4): p. 2073-2082.
44. Thürling, M., et al., Involvement of the cerebellar cortex and nuclei in verbal and visuospatial working memory: A 7T fMRI study. NeuroImage, 2012. **62**(3): p. 1537-1550.
45. Shum, D.H., J.G. O'Gorman, and K. Eadie, *Normative data for a new memory test: the Shum Visual Learning Test.* Clin Neuropsychol, 1999. **13**(2): p. 121-35.
46. Eadie, K. and D. Shum, Assessment of visual memory: A comparison of Chinese characters and geometric figures as stimulus materials. Journal of Clinical and Experimental Neuropsychology, 1995. **17**: p. 731-739.
47. Maljkovic, V. and K. Nakayama, *Priming of pop-out: II. The role of position.* Perception & Psychophysics, 1996. **58**(7): p. 977-991.
48. Neill, W.T. and A.L. Kleinsmith, *Spatial negative priming: Location or response?* Attention, Perception, & Psychophysics, 2016. **78**(8): p. 2411-2419.
49. Fukuda, K. and E.K. Vogel, *Individual differences in recovery time from attentional capture.* Psychological Science, 2011. **22**(3): p. 361-368.
50. Konstantinou, N., E. Beal, J.-R. King, and N. Lavie, *Working memory load and distraction: Dissociable effects of visual maintenance and cognitive control.* Attention, Perception, & Psychophysics, 2014. **76**(7): p. 1985-1997.
51. Roper, Z.J.J. and S.P. Vecera, *Visual short-term memory load strengthens selective attention.* Psychonomic Bulletin & Review, 2014. **21**(2): p. 549-556.
52. Winkler, I., S. Debener, K.R. Müller, and M. Tangermann. On the influence of high-pass filtering on ICA-based artifact reduction in EEG-ERP. in 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). 2015.
53. Braver, T.S., The variable nature of cognitive control: a dual mechanisms framework. Trends in Cognitive Sciences, 2012. **16**(2): p. 106-113.
54. Corriveau, I., et al., Electrophysiological evidence of multitasking impairment of attentional deployment reflects target-specific processing, not distractor inhibition. International Journal of Psychophysiology, 2012. **86**(2): p. 152-159.
55. Fortier-Gauthier, U., et al., Contralateral cortical organisation of information in visual short-term memory: Evidence from lateralized brain activity during retrieval. Neuropsychologia, 2012. **50**(8): p. 1748-1758.
56. Leblanc, É., D.J. Prime, and P. Jolicoeur, *Tracking the Location of Visuospatial Attention in a Contingent Capture Paradigm.* Journal of Cognitive Neuroscience, 2008. **20**(4): p. 657-671.
57. Barras, C. and D. Kerzel, Active suppression of salient-but-irrelevant stimuli does not underlie resistance to visual interference. Biological Psychology, 2016. **121**: p. 74-83.
58. Barras, C. and D. Kerzel, Salient-but-irrelevant stimuli cause attentional capture in difficult, but attentional suppression in easy visual search. Psychophysiology, 2017. **54**(12): p. 1826-1838.
59. Jannati, A., J.M. Gaspar, and J.J. McDonald, *Tracking target and distractor processing in fixed-feature visual search: evidence from human electrophysiology.* Journal of experimental psychology. Human perception and performance, 2013. **39**(6): p. 1713-1730.
60. Eysenck, M.W., N. Derakshan, R. Santos, and M.G. Calvo, *Anxiety and cognitive performance: Attentional control theory.* Emotion, 2007. **7**(2): p. 336-353.