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Exploring the Effects of Service Dogs: Enhanced Working Memory in Police Officers With Post-Traumatic Stress Disorder

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ABSTRACT
Post-traumatic stress disorder (PTSD) is associated with decreased executive functioning due to an imbalance in the frontal-amygdala circuit. Researchers theorize that an overactive amygdala increases the demand for regulating stress-related responses, thus depleting the prefrontal cortex of the limited resources needed for executive functions such as working memory. We hypothesized that working memory performance in people with PTSD could be partially restored by the presence of their dog, potentially working as a stress buffer. This study investigated the effect of the presence of a dog on working memory performance in police officers ($n = 49$) either with PTSD ($n = 25$) or without PTSD ($n = 24$), using behavioral and electrophysiological measures. Working memory performance was assessed on a 1-back task, both in the presence and absence of the participants' companion or service dog. We measured event-related potentials (ERPs), with a focus on the N2 and P3 components. The results show that police officers with PTSD exhibited improved working memory performance in the presence of their dog, as evidenced by enhanced task performance and a larger N2 component amplitude to target stimuli compared with when the dog was absent. In contrast, the police officers without PTSD showed, in the absence of the dog, a better task performance and a larger N2. The findings suggest that the presence of a dog enhances working memory performance in police officers with PTSD.

KEYWORDS
ERP; human–animal interaction; police; PTSD; service dog; working memory

In individuals with post-traumatic stress disorder (PTSD), inhibitory control primarily serves to suppress recurrent, involuntary, and intrusive memories of the traumatic event to reduce the impact of stressors and triggers (Hayes et al., 2012). The symptom of reexperiencing, therefore, places great strain on executive functioning, reducing the

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allocation of resources to everyday executive functions such as working memory (Bomyea et al., 2012). Inhibitory control and working memory are two core executive functions that are closely related and support one another (Diamond, 2013). Inhibitory control refers to the cognitive process that enables an individual to regulate attention, behavior, thoughts, and emotions by suppressing impulses or distractors. Working memory involves holding information in mind and mentally working with it. Working memory and inhibition depend on the same limited-capacity system of executive functions (Figure 1); increasing the demand on either of them affects the ability to do the other (Diamond, 2013).

Increased demands on inhibitory control capacity could result from the hyperactivation of the amygdala in individuals with PTSD (Selemon et al., 2019). In this context, the negative relationship between executive functions and reexperiencing symptoms can be explained by an imbalance of the fronto-amygdala circuit. PTSD causes increased amygdala activity (Luethi et al., 2009), resulting in an increased responsiveness to potentially threatening stimuli. Consequently, the hyperactive amygdala demands enhanced inhibitory control in order to regulate stress-induced responses (McKlveen et al., 2015). When the prefrontal cortex (PFC) needs to allocate its resources to regulate excessive responses to external stimuli, fewer resources remain available (Figure 1). Adequate resources are essential for executive functions, enabling the successful performance of tasks that require working memory and other executive functions crucial for daily activities (Salzman & Fusi, 2010). Persistent stress in PTSD limits the capacity of the frontal cortex for executive functions, including working memory (Westphal et al., 2021).

Considering that persistent stress is associated with decreased executive functioning in individuals with PTSD (Woon et al., 2017), interventions that attenuate stress responses

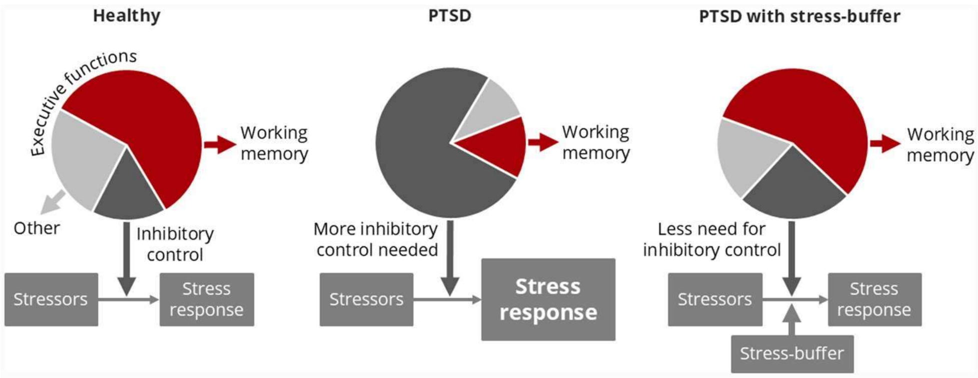

Figure 1. Conceptual model of executive functions and stress-buffering.

Note: The circle diagram depicts the limited capacity system of executive functions. In healthy individuals, exposure to stressors leads to normal physical and psychological stress responses. These stress responses can be managed with minimal inhibitory control, leaving sufficient resources for other executive functions, including working memory processes. As a result, performance on working memory tasks is effective in standard situations. In individuals with PTSD, exposure to stressors results in excessive stress responses. Controlling these heightened responses requires substantial inhibitory control, depleting the executive function resources to be allocated to other executive functions, including working memory, leading to diminished performance on a working memory task. The presence of a stress buffer may mitigate the psychological and physiological stress response. When a stress buffer is present, the stress response may be reduced, less inhibitory control is needed, and more resources remain available for working memory. Thus, the performance on the working memory task may be partially restored. The figure is a combination of an executive functions model (Diamond, 2013) and a stress-buffering model (Masson et al., 2019).

may help restore these executive functions. Research shows that dogs may have stress-reducing effects (Polheber & Matchock, 2014). A meta-analysis revealed that the presence of a dog during psychotherapy can lower physiological and subjective stress levels (Ein et al., 2018). In the context of traumatic stress, studies show that dogs can significantly reduce acute distress (Hunt & Chizkov, 2014) and alleviate subjective feelings of stress and anxiety both during and after an experimental traumatic stress situation (Lass-Hennemann et al., 2014, 2018). Most research on dogs for PTSD so far has been done on veterans (Krause-Parello et al., 2016; Stern et al., 2013; Yarborough et al., 2018).

The presence of dogs may have a positive effect on working memory functioning in people with PTSD. One potential mechanism for a positive effect of a dog could be stress buffering (Kikusui et al., 2006). Stress buffering is the reduction of psychological and physiological stress responses through various factors (Hornstein & Eisenberger, 2017). One form of stress buffering is social buffering, where the presence of a supportive individual helps alleviate stress. Stress buffering contributes to reducing amygdala activity (Mulej Bratec et al., 2020). The reduction in amygdala activity allows the prefrontal cortex (PFC) to allocate resources to executive functions instead of regulating excessive responses to external stimuli. Therefore, people with PTSD may perform better on, for example, a working memory task in the presence of a stress buffer compared with the absence of a stress buffer. If dogs act as stress buffers, their presence may reduce the need for inhibitory control, leaving more resources for other executive functions (Figure 1).

Working memory tasks have been widely used to test executive functions in people with PTSD (Honzel et al., 2014). Research shows that PTSD patients perform poorly on neutral working memory tasks in terms of both response speed and accuracy (Quinones et al., 2020). This study aimed to investigate the effect of the presence compared with the absence of a dog on performance on a neutral 1-back working memory task as an indicator of executive functioning in police officers with PTSD. We hypothesized that the presence of a dog restores working memory performance compared with situations without a dog in police officers with PTSD. To test our hypothesis, we examined both overt responses (such as reaction times and errors) and covert responses using neurophysiological measurement techniques (Van Houtert et al., 2018). Such research could offer an evidence-based rationale for using dogs to enhance various outcomes, including improvements in executive functions, which are essential for performing daily activities.

To determine changes in covert behavior related to working memory performance following stress buffering, we also examined event-related potentials (ERPs) extracted from electroencephalogram (EEG) recordings made during the working memory task (Veltmeyer et al., 2009). ERPs are the average brain responses time-locked to a specific event and are characterized by positive and negative components labeled with a letter indicating polarity, followed by a number indicating the order in which they appear. Among the ERP components, N2 and P3 component amplitudes have been reliably associated with WM function (Peng et al., 2020; Stroux et al., 2016). The N2 component is a negative wave reaching maximum amplitude between 200 and 350 ms post-stimulus and is assumed to be an indicator of inhibition, feedback processes, and conflict monitoring (Miller et al., 2021). The P3 is a positive component reaching maximum amplitude between 300 and 500 ms post-stimulus and is associated with attention control and memory updating (Patel & Azzam, 2005).

This study examined the impact of dog presence on working memory performance among police officers with ($n = 25$) and without PTSD ($n = 24$). We hypothesized that the presence of their dog enhances working memory performance in those with PTSD compared with the absence of their dog. An improved working memory performance would be reflected in higher scores on the 1-back task and increased amplitudes in both the ERP N2 component and the P3 component.

In addition to our primary hypothesis, we also explored the potential differences between a specifically trained PTSD service dog and an untrained companion dog in the effect on restoring working memory in police officers with PTSD. The stress-buffering effect of a dog may depend on whether the dog has been specifically trained as a service dog to help reduce PTSD symptoms and stress responses (Van Houtert et al., 2018). This exploratory analysis may provide insights into the potential benefits of companion versus service dogs for police officers with PTSD.

Methods

The study was reviewed independently by the Ethics Committee Social Sciences (ECSS) of the Radboud University. There was no formal objection to it (ECSW-2020-012).

Participants

The participants were recruited through internal communication within the Dutch police. In total, 57 police officers agreed to participate in the study. All participants provided written informed consent. To be included in the PTSD group, participants needed to have a work-related PTSD diagnosis provided by a mental health professional of the police force, have finished at least one type of treatment, owned a service or companion dog for at least six months, and be (or have been) employed within the police force. Two of the participants with a service dog were no longer employed anymore within the police force; all the other participants were still employed. In the group with PTSD, 16% had worked in the police force for fewer than 15 years, 48% had worked for 15–30 years, and 12% had worked for more than 35 years. For six participants, we did not have their employment duration data (24%). Two-thirds of the group with PTSD who had a companion dog used medication, and 54% of the group with PTSD with a service dog used medication. An overview of the used medication in the group with PTSD is provided in the online supplemental material (Table S9).

To determine if the PTSD diagnosis was still current, interview responses were evaluated after data collection to determine if symptoms were still present. Based on the symptoms mentioned during the interview, seven participants were excluded due to (almost full) remission of PTSD. Additionally, the EEG data of one participant could not be collected and was therefore excluded from the analysis.

For the control group, inclusion criteria were being (or have been) employed within the police force, owning a companion dog for at least six months, and having no current or past diagnosis of PTSD. The police officers with PTSD ($n = 25$; 17 men, 8 women; mean age = 48.4 years, $SD = 11.0$) had either a trained dog (PTSD service dog, $n = 12$; 9 male dogs, 3 female dogs) or a companion dog ($n = 13$; 8 male dogs, 5 female dogs), while the police officers without PTSD ($n = 24$; 6 men, 18 women; mean age = 49.0 years old, $SD = 10.7$) all had a companion dog.

The companion dogs were all kinds of breeds and did not receive training aimed at PTSD symptoms. The service dogs were all labradors bred and trained by the KNGF, the Royal Dutch Guide Dog Foundation. The KNGF trains guide dogs for visually impaired people and, amongst others, for people with PTSD. Service dogs are trained to the user's specific needs; for example, waking up their owner in the early stages of a nightmare, ensuring sufficient personal space by preventing other people to come close, and acting as a reassuring and ever-present buddy.

Power Analysis

An a priori power analysis was conducted using G*Power (Faul et al., 2007) to determine the required sample size for a repeated-measures ANOVA with a within-subjects factor (dog presence: present vs. absent) and a between-subjects factor (group: PTSD vs. control). The analysis was based on a moderate effect size (Cohen's $f = 0.25$), an alpha level of 0.05, and a power of 0.80. The results indicated that a total sample of 34 participants was needed to detect a significant interaction effect.

A separate power analysis was conducted for the N2 and P3 component amplitudes using a repeated-measures ANOVA with three within-subject factors (dog presence, trial type, electrode site) and one between-subjects factor (group). A small to moderate effect size (Cohen's $f = 0.25$) was assumed, with an alpha level of 0.05 and power of 0.80, which is common in ERP experiments (Butt et al., 2019). The analysis suggested that a total of 16 participants would be required to detect significant effects reliably.

Given the available sample size ($n = 12$ for the service dog group and $n = 13$ for the companion dog group), a post-hoc sensitivity analysis was conducted to determine the minimum detectable effect size. Assuming an alpha level of 0.05 and a power of 0.80, the analysis indicated that the smallest detectable effect size for a repeated-measures ANOVA was $f = 0.29$. Thus, while our study was sufficiently powered to detect medium to large effects, smaller effects could not be reliably detected.

Procedure

This study was part of a larger project aiming to investigate the added value of the service dog (Smit et al., 2022). A qualitative study was conducted in parallel with this project, though its objectives fall outside the scope of the present analysis. This current study used an experimental design to compare working memory performance between police officers with and without PTSD and compare the effect on working memory performance of a dog's presence with its absence. To achieve this, data were collected in two subsequent sessions on the same day, one with the dog present and one with the dog absent, in both the control and experimental groups. Each condition lasted approximately 20 min. For ethical reasons, the conditions were not counterbalanced as the absence of a service dog would have had a significant impact on the group with PTSD; beginning the experiment without the dog would have been excessively stressful for this group. The complete experiment, including EEG preparation, lasted approximately one hour.

At the start of the task, instructions were provided both verbally by the researcher and presented on-screen as text. Participants were given the option to take breaks between experiments and sessions, though few chose to do so. During the task in the dog-present condition, the dog was close to the participant, either laying down loose or on a leash to create the most natural setting (Gee et al., 2015). When participants performed tasks without the dog, the dog was cared for in a separate room by either an accompanying relative or a second researcher.

Measures

1-Back Task

The 1-back task was created using Presentation software (Version 17.0, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com) and was displayed on a 21.5-inch LCD computer monitor with a refresh rate of 60 Hz. During the task, participants were required to press a key when the stimulus of the current trial matched the stimulus they saw one step back (1-back, Figure 2). The task used nine different single digits in version A (1, 2, 3, 4, 5, 6, 7, 8, 9) and nine different single letters in version B (A, B, C, D, E, F, G, H, K) as stimuli. Each participant completed both versions, A and B, in a counterbalanced order. The stimuli were presented in white against a black background in a 20-point font size for 500 ms, followed by 2,000 ms of black screen. Each trial lasted 2,500 ms.

Each version of the 1-back task consisted of 96 trials: 32 target trials, where participants had to press the button, and 64 background stimuli, where no button press was required. The task lasted approximately 5 min, including task instructions. About 15 min of other tasks were in between the two N-back tasks. The sequences of targets and background stimuli were pseudo-randomly generated. We calculated the balanced integration score (BIS) as suggested by Liesefeld and Janczyk (2019) to evaluate the speed and accuracy

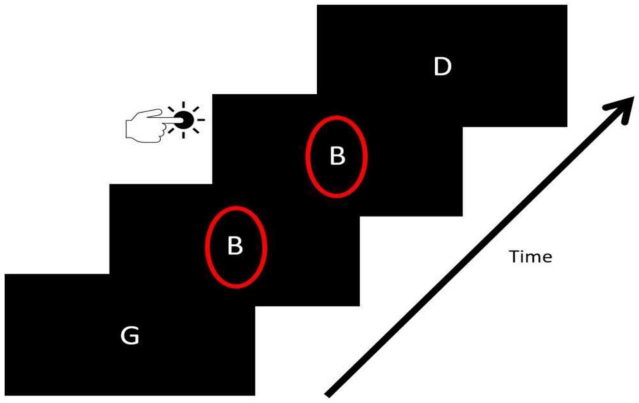

Figure 2. 1-back task.

Note: In the 1-back task, participants were instructed to press a response button if the presented letter was the same as the previous letter (one back). The stimuli were presented for 500 ms, followed by 2,000 ms of black screen.

of performance. The BIS is commonly used to decrease intra-individual variability concerning speed-accuracy tradeoffs. The BIS was computed by first standardizing reaction times and proportions correct to bring them to the same scale and then subtracting one standardized score from the other. The mean and standard deviation were calculated over all subjects and all conditions.

EEG Recording and Preprocessing

The EEG setup utilized the BrainProducts ActiCap 32-channel active EEG system, positioned according to the 10–20 system standard electrode placements. In the current study, we used four scalp electrodes (Fz, Cz, Pz, Oz), two electrodes for recording the electrooculogram located below and lateral to the outer canthus of the left eye, and a reference and ground electrode on the left and right mastoid, respectively. The limited number of electrodes was due to the COVID-19 pandemic, as we needed to minimize close contact time with participants. The electrode-scalp impedance was reduced to less than 20 kΩ for all electrodes. EEG data were recorded at a 500 Hz sampling rate using an amplifier with an input impedance of 10 MΩ.

Offline data analysis was conducted using BrainVision Analyzer (BrainVision Analyzer, Version 2.2.0, Brain Products GmbH, Gilching, Germany). The data were digitally filtered with 0.5 Hz high-pass and 30 Hz low-pass filters. ERP segments were set from 250 ms before stimulus onset until 750 ms after stimulus onset. Following segmentation, a DC detrend and a Gratton & Coles ocular correction without raw average subtraction were applied.

We excluded segments containing incorrect responses (false hits, misses), segments with an amplitude exceeding ± 100 µV, and segments with activity below 0.5 µV for 100 ms or more from further analyses. The average percentage of included segments was 97.9% (*SD* 2.5), with a minimum of 24 segments (out of 32) of the target stimuli per participant. Lastly, a 100 ms baseline correction was applied. We obtained ERPs by averaging segments separately for background and target stimuli.

Fixed time windows were defined for the ERP N2 and P3 components based on the combined data from both groups in an across-condition grand average, following the recommended approach in the literature (Kappenman & Luck, 2016). We calculated the average amplitude of the ERP N2 component within a fixed latency window of 200–300 ms. Similarly, the average amplitude of the ERP P3 component was determined within the fixed latency window of 380–480 ms.

Statistical Analyses

The statistical analysis was performed using IBM SPSS Statistics (Version 27). To examine differences in task performance, we conducted a Generalized Linear Model (GLM) analysis on the corrected reaction time (BIS) with a within-subjects factor of condition (dog present vs. dog absent), a between-subjects factor of group (PTSD vs. control group), and gender (male vs. female) as covariate. On the N2 and P3 component amplitudes, two GLM analyses were performed with group (PTSD vs. control) as the between-subject variable, condition (dog present vs. dog absent), trial type (background vs. target), and electrode (Fz, Cz, Pz, Oz) as the within-subject variables, and gender (male vs. female) as covariate. When the assumption of sphericity was violated, we used the Greenhouse-Geisser correction. Significant interactions were followed up using *t*-tests.

To examine potential differences in working memory performance among police officers with PTSD based on the level of training their dog had received, the PTSD group was further analyzed by exploring the effects of the presence of a trained service dog ($n = 12$) versus a companion dog ($n = 13$). We conducted a repeated-measures GLM on the corrected reaction time to examine whether there were any performance differences between the two subgroups on the working memory task and whether the presence of a dog affected performance. Additionally, for the N2 and P3 component amplitudes to the background and target stimuli, we used four GLM analyses with electrode (Fz, Cz, Pz, Oz) and condition (dog present vs. dog absent) as within-subject variables, group (service dog vs. companion dog) as a between-subject variable, and gender (male vs. female) as covariate.

Results

Performance on the Working Memory Task

The percentage of correct trials and reaction times is provided in the online supplemental material (Table S1). Analysis of the score on the working memory task (BIS) revealed a significant interaction effect of condition × group ($F_{(1,46)} = 10.52$, $p = 0.002$, $\eta^2 = 0.19$). Pairwise comparisons per group showed that the control group scored higher (faster and/or made fewer errors) when the dog was absent compared with when the dog was present ($t_{(23)} = -3.20$, $p = 0.004$, $d = -0.65$). The group with PTSD scored significantly lower (slower and/or made more errors) when they completed the task without their dog compared with when their dog was present ($t_{(24)} = 2.18$, $p = 0.039$, $d = 0.44$) (Figure 3). There was no main effect

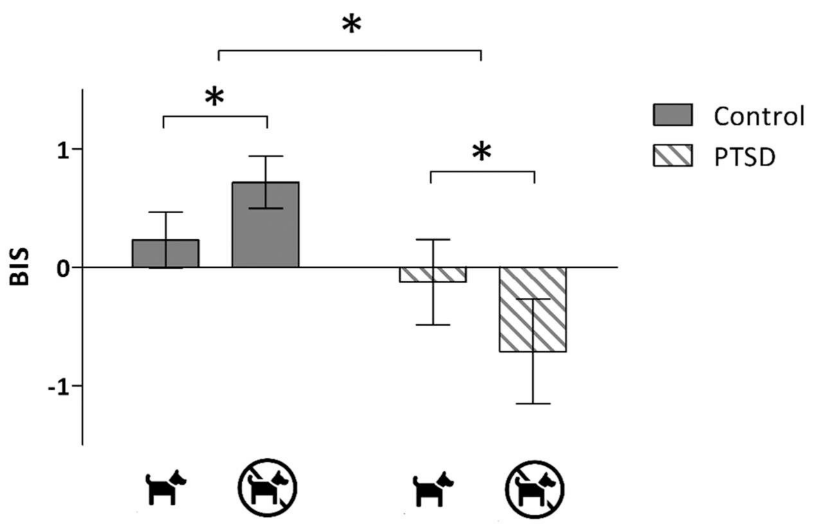

Figure 3. Balanced integration scores (BIS) on the 1-back task.

Note: BIS corrected for gender with SEM for each group in the two conditions (with dog and without dog).

of group ($F_{(1,46)} = 0.88$, $p = 0.354$, $\eta^2 = 0.02$) or condition ($F_{(1,46)} = 0.26$, $p = 0.613$, $\eta^2 = 0.01$). A main effect of gender was found ($F_{(1,46)} = 5.01$, $p = 0.030$, $\eta^2 = 0.10$), and no interaction effects with gender, indicating that the women scored significantly better than the men.

The ERP N2 Component Amplitude

Figure 4 shows the grand averages of the ERPs, illustrating the average response of participants to the stimuli presented. See the online supplemental material for full statistical results (Table S2). The primary GLM revealed interaction effects with stimulus type (target, background). Consequently, we conducted separate GLM analyses for both stimulus types. In these analyses, we included electrode (four levels: Fz, Cz, Pz, Oz) and condition (two levels: dog present, dog absent) as within-subject variables, group (two levels: PTSD, control) as a between-subjects variable, and gender (two levels: male, female) as a covariate. On the target stimuli, we found an interaction effect of condition × group ($F_{(1,46)} = 5.63$, $p = 0.022$, $\eta^2 = 0.11$) and an interaction effect of condition × electrode × group ($F_{(3,130)} = 4.57$, $p = 0.005$, $\eta^2 = 0.09$). Pairwise comparisons within the control group

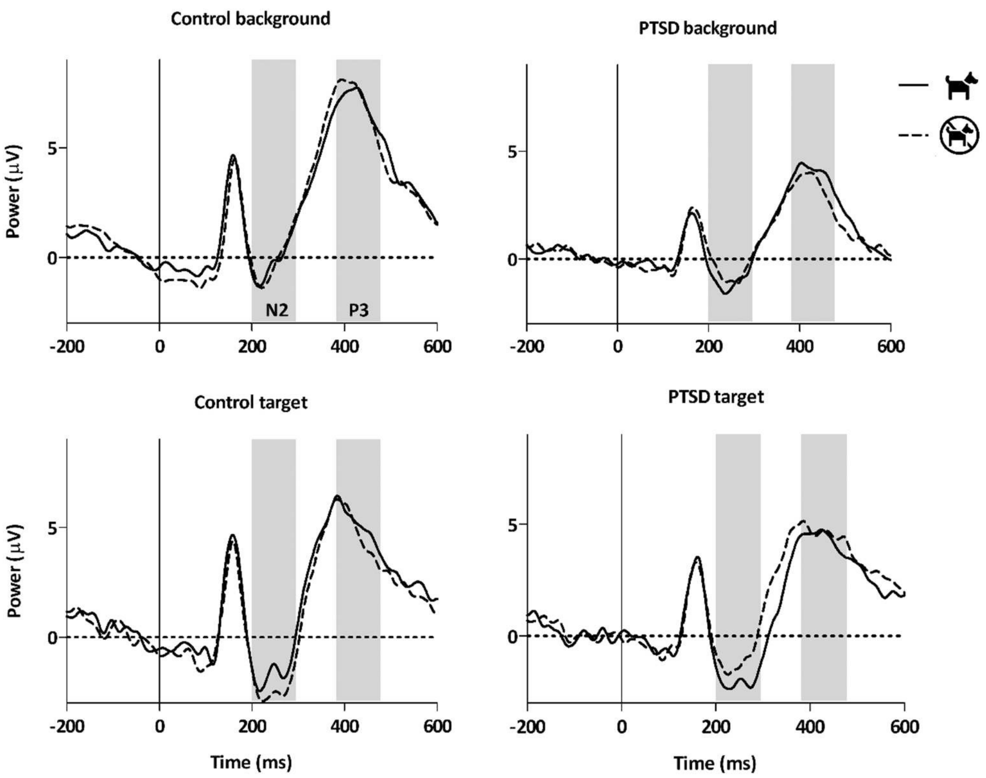

Figure 4. Event-related potentials (ERPs) 1-back task.

Note: Grand averages on electrode Cz for the background stimuli (top panels) and the target stimuli (bottom panels) for the control group (left) and the PTSD group (right). Solid line: dog present, dashed line: dog absent. The N2 ERP component is indicated by the first gray area (200–300 ms), while the second gray area indicates the P3 ERP component (380–480 ms).

revealed a larger (more negative) N2 amplitude when the dog was absent compared with when the dog was present ($t_{(23)} = -2.76$, $p = 0.011$) (Fz). Additionally, for the group with PTSD, pairwise comparisons showed that the amplitude of the N2 was larger (more negative) when the dog was present compared with when it was absent on Fz ($t_{(24)} = 2.60$, $p = 0.016$) and on Cz ($t_{(24)} = 2.88$, $p = 0.008$).

On the target stimuli, we did not find any main effects, apart from a significant main effect of electrode ($F_{(2,97)} = 16.85$, $p < 0.001$, $\eta^2 = 0.27$). With respect to the background stimuli, except for a main electrode effect with a maximum amplitude on electrode Fz ($F_{(2,94)} = 16.05$, $p < 0.001$, $\eta^2 = 0.26$), no significant differences in the N2 amplitudes were observed. In summary, the results indicate a more pronounced (more negative) N2 amplitude to target stimuli in the PTSD group when the dog was present, and in the control group when the dog was absent. A complete overview of the statistical analyses of the N2 is provided in the online supplemental material (Table S3).

The ERP P3 Component Amplitude

The results of the primary GLM on the P3 component amplitudes (see online supplemental Table S4) revealed significant interaction effects with stimulus, which prompted us to conduct separate analyses elicited by target and background stimuli. For this purpose, we employed two GLM analyses, using electrode (Fz, Cz, Pz, Oz) and condition (dog present vs. dog absent) as within-subject variables, group (PTSD vs. control) as between-subjects variable, and gender (male vs. female) as covariate. For the target stimuli, no significant effects were found except a main effect of electrode ($F_{(2,100)} = 11.88$, $p < 0.001$, $\eta^2 = 0.21$). With respect to the background stimuli, a significant interaction effect of electrode × condition was observed ($F_{(2,100)} = 3.87$, $p = 0.021$, $\eta^2 = 0.08$). However, a paired *t*-test with dog absence versus dog presence per electrode did not yield any significant effect ($p > 0.1$). No main or interaction effects of gender were found ($F_{(1,46)} = 0.28$, $p = 0.100$, $\eta^2 = 0.01$).

A main effect of electrode with a maximum amplitude over electrode Pz was observed ($F_{(1,46)} = 13.60$, $p < 0.001$, $\eta^2 = 0.23$). We found a significant main effect of group for P3 amplitude to the background stimuli ($F_{1(1,46)} = 5.15$, $p = 0.028$, $\eta^2 = 0.10$), with a lower P3 amplitude in the group with PTSD than in the control group. Overall, these findings demonstrate that the individuals with PTSD exhibited a lower P3 amplitude to background stimuli compared with the control group. A complete overview of the statistical analyses of the P3 is provided in the online supplemental material (Table S5).

Comparing the Presence of a Companion Dog with the Presence of a Service Dog

For exploratory purposes, we further analyzed the data from the PTSD group by comparing police officers with a companion dog ($n = 13$) with those with a trained service dog ($n = 12$). The percentage of correct trials and reaction times per group (Table S6) and an overview of the statistical analyses (Tables S7 and S8) are provided in the online supplemental material. Our analyses of the score on the working memory task (BIS) revealed no interaction effects and no main effect of group (companion dog vs. service dog) ($F_{(1,22)}$

$= 2.92$, $p = 0.102$, $\eta^2 = 0.12$). We did find a main effect of gender ($F_{(1,22)} = 4.46$, $p = 0.046$, $\eta^2 = 0.17$): women scored significantly better than did men.

With respect to the ERP N2 component, we found interaction effects with stimulus type, therefore, background and target stimuli were analyzed separately. On the target stimuli, we found a main effect of electrode and no other effects. On the background stimuli, interaction effects of condition × gender, condition × electrode, and condition × electrode × gender were found, with only in women a larger (more negative) N2 amplitude when the dog was present compared with when the dog was not present ($p < 0.033$) on all electrodes. In men, no significant effect was found ($p > 0.1$). Additionally, we found a main effect of electrode, a main effect of condition ($F_{(1,22)} = 17.10$, $p < 0.001$, $\eta^2 = 0.44$), and a main effect of gender ($F_{(1,22)} = 5.02$, $p = 0.035$, $\eta^2 = 0.19$).

With respect to the ERP P3 component, an interaction effect with stimulus type was found; therefore, one GLM for target stimuli and one GLM for background stimuli were performed. For target stimuli, no group differences were observed. There was an interaction effect of condition × gender, with a higher P3 when the dog was present in women; however, post-hoc tests revealed no significant differences. On the background stimuli, interaction effects of condition × group ($F_{(1,22)} = 9.31$, $p = 0.006$, $\eta^2 = 0.30$) and electrode × condition × group were found ($F_{(2,45)} = 3.37$, $p = 0.042$, $\eta^2 = 0.13$). A GLM for each group with electrodes separate showed that the P3 amplitude was significantly higher (on Fz, Cz, and Pz) when the dog was present compared with when the dog was absent, but only in the group with the service dog ($F_{(1,11)} = 15.68$, $p = 0.002$, $\eta^2 = 0.59$) (electrode Cz), and not in the group with the companion dog ($F_{(1,12)} = 2.87$, $p = 0.116$, $\eta^2 = 0.19$) (electrode Cz). Overall, these results show a higher P3 amplitude to background stimuli in the group with the service dog compared with the group with the companion dog, when the dog was present.

Discussion

The study investigated the impact of the presence of a service or companion dog on the working memory performance of police officers with PTSD compared with a control group of police officers without PTSD, using behavioral and electrophysiological measures. Our findings indicate that police officers with PTSD perform better on a working memory task in the presence of their service or companion dog.

We hypothesized that the presence of a dog enhanced working memory performance in police officers with PTSD compared with the absence of a dog. The results support this hypothesis as the improvement in working memory performance in the presence of a dog was only found in the PTSD group and not in the control group. The improvement in working memory performance in the PTSD group aligns with our conceptual model presented in the introduction (Figure 1), suggesting that the presence of a dog enhances executive functioning, potentially due to stress-buffering effects. This result was supported by the physiological data showing a larger N2 component amplitude in response to target stimuli when the dog was present in the group with PTSD. The N2 component reflects inhibition and feedback processes (Miller et al., 2021); its larger amplitude when the dog was present suggests enhanced capacity devoted to these functions. In the absence of the dog, the lack of a stress buffer could cause attention to shift from the task to the surroundings, leading to a depletion of frontal resources essential for executive functioning (Schweizer & Dalgleish, 2011).

The control group (police officers without PTSD) performed significantly better in the absence of their dog compared with the presence of their dog as indicated by higher scores on the working memory task and a larger N2 component amplitude when the dog was absent. One explanation for this outcome is the effect of repeated testing, or learning effects, as the order of the conditions of dog presence was not counterbalanced. The control group likely experienced lower stress levels than the PTSD group, enabling it to benefit more from repeated exposure to the task, resulting in improved performance without the dog. Another explanation may be that the presence of the dog diverted attention in the control group, consuming executive function resources needed for task engagement and leading to poorer performance. This explanation is supported by the finding of a larger N2 amplitude in the control group when the dog was absent, suggesting increased attentional engagement to the task (Folstein & Van Petten, 2008).

In addition to our main findings, our results revealed a significant gender effect on working memory performance, with women outperforming men. However, this effect must be interpreted with caution due to the unequal gender distribution between groups, which may have influenced the results. The PTSD group was predominantly male (17 men, 8 women), whereas the control group was predominantly female (6 men, 18 women). This imbalance is noteworthy because the observed gender differences in working memory may have been amplified by the group composition rather than reflecting a true biological difference.

A meta-analysis by Wang et al. (2019) found no significant gender differences in N-back working memory performance, suggesting that our findings may have been driven by factors other than inherent cognitive differences between men and women. The overrepresentation of women in the control group could have contributed to their superior performance as previous research indicates that individuals with PTSD generally exhibit impaired working memory (Nejati et al., 2018). Thus, the gender effect observed in our study may partly result from the interaction between PTSD diagnosis and gender distribution rather than a gender-based advantage in working memory. However, our exploratory analysis also indicated that women with PTSD performed significantly better than men, though this finding was based on a small sample; no conclusions should be drawn from this. Future studies should aim for more balanced group compositions to clarify the relationship between gender, PTSD, and working memory.

Supporting the arguments for a group difference based on PTSD diagnosis, we observed a lower ERP P3 component amplitude in individuals with PTSD compared with the control group. This finding is in alignment with the literature showing lower P3 amplitudes to neutral stimuli in PTSD (Johnson et al., 2013). A lower P3 amplitude may indicate difficulties in updating working memory, which is supported by previous findings of abnormal working memory functioning in individuals with PTSD (Javanbakht et al., 2011; Johnson et al., 2013; Moores et al., 2008; Shaw et al., 2009). The group effect was observed with background stimuli and not with target stimuli. This result can be explained by the theory that the P3 component is associated with memory updating (Patel & Azzam, 2005), which is primarily triggered by background stimuli rather than target stimuli during the 1-back task.

We also explored whether the presence of a trained service dog would yield greater stress-buffering effects than that of an untrained companion dog. Although police officers with PTSD exhibited similar working memory performance with both types of dogs, we noted an interaction effect regarding the ERP P3 component amplitude, despite a small sample size. The P3 amplitude in response to background stimuli was higher in the service dog group, which may reflect enhanced resource allocation toward working memory (Javanbakht et al., 2011). This result has two possible explanations. First, the service dog may reduce the owner's stress response by simply being present, freeing up cognitive resources for the task. Alternatively, companion dogs may have been more distracting than the trained service dogs.

Understanding the connection between stress, executive functions, and PTSD symptoms is important for uncovering the cognitive mechanisms underlying PTSD. We based our hypotheses on the theory that reduced executive functioning results from hyperactivation of the amygdala coupled with increased demands on the prefrontal cortex (Selemon et al., 2019). In contrast, other studies suggest that individuals with poorer executive functions are more vulnerable to psychopathology after extreme stress due to their diminished capacity to regulate intrusive cognitions (Bomyea et al., 2012). Future research should further explore the relationship between PTSD symptoms, stress levels, and frontal resource depletion. Additionally, investigating how service dogs influence stress levels directly could provide valuable insights into their therapeutic potential for individuals with PTSD. Survey studies consistently report that service dogs have stress-reducing abilities beneficial for veterans with PTSD (Kloep et al., 2017; O'Haire & Rodriguez, 2018; Rodriguez et al., 2020). Our research could not determine if dog presence and changes in working memory performance are directly associated with stress levels, so future work should focus on this using physiological measurements to gain a better understanding of this topic.

Limitations

Several limitations of our study require consideration. First, conditions could not be counterbalanced because of ethical reasons. The absence of especially a service dog would have a big impact on the owner in the group with PTSD; it would have been too stressful to start with the dog-absent condition. As a consequence, the results should be interpreted with caution; more research is needed to draw firm conclusions. While fatigue may occur more easily in individuals with PTSD, additional analyses of reaction times revealed no evidence of fatigue-induced slowdowns during tasks.

Second, we did not conduct a clinical assessment of PTSD symptoms at the study's onset, relying instead on current diagnoses for inclusion, which may have led to variability in symptom severity within the experimental group. Third, a gender imbalance existed between the experimental (17 men, 8 women) and control groups (6 men, 18 women). Fourth, we could not control for medication use, which may influence cognitive control and working memory in police officers with PTSD (Bymaster et al., 2002), leaving the potential for unaccounted effects on task performance and ERP components. An overview of medication use in the PTSD group is provided in the supplemental material. Finally, despite significant ERP findings, the effect sizes were small, emphasizing the need for replication of these results.

Conclusion

In conclusion, our findings suggest that the presence of a dog enhances working memory performance in individuals with PTSD. The potential stress-buffering effects of the dog's presence may underlie these benefits, making this study an important step in uncovering the mechanisms through which service dogs can reduce PTSD symptoms. The daily presence of a dog may help regulate stress responses and mitigate executive function impairments. The findings support the integration of dogs into therapeutic options for police officers with PTSD. Law enforcement agencies should consider expanding programs that provide service dogs to officers suffering from severe PTSD, helping those who have not benefited from traditional treatments or continue to experience persistent symptoms.

Data Availability Statement

The data that support the findings of this study are available in the Radboud Repository: https://doi.org/10.34973/m38q-cz87.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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