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Research Article

Failure of tDCS to impact militarised threat-detection in a military cohort

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ABSTRACT

Transcranial direct current stimulation (tDCS), a form of non-invasive brain stimulation, has become a focus of military organisations due to its reported positive effects on cognitive and motor performance. However, the majority of tDCS research in this space is conducted with civilian participants and/or uses abstract tasks. Additionally, of the small subset of studies that have used military participants or military-relevant tasks, few have employed both, and none with a considerable sample size. Here, we extend on previous work by exploring whether tDCS to the right inferior frontal gyrus (rIFG) enhances the performance of a large military cohort during a militaristic threat-detection task. 98 participants aged between 18 and 45 were randomly assigned to one of three conditions: (1) 2 mA anodal tDCS to the rIFG; (2) Sham stimulation to the rIFG; or (3) 2 mA anodal tDCS to the visual cortex (V1). Participants viewed serially presented, virtually generated militaristic images, and responded Yes/No via keypress to a threat being present. tDCS was applied for 25 min during the first two training blocks of the 50 min task. Results showed evidence for the null hypothesis: tDCS did not influence mean accuracy or reaction time across the task, in contrast to previous work. We discuss possible methodological and population factors that may explain why previously published effects of tDCS were not reproduced.

Keywords: tDCS, prefrontal cortex, visual search, military, cognitive performance

1. BACKGROUND

An individual's ability to perceive and detect targets within their visual field is vital in military operations, where personnel may find themselves searching for a hidden target (e.g., via camouflage) from the cockpit of an aircraft, the bridge of a ship, or the turret of a tank. While personnel in these roles receive extensive training, including on optimal visual search tactics, there exists considerable interest in interventions that may boost generalised performance during sustained visual search tasks.

Transcranial direct-current stimulation (tDCS), a form of non-invasive brain stimulation, is one such intervention that already features heavily in military-related research where it has been shown to combat fatigue (McIntire et al., 2017), augment working memory (Nelson et al., 2016), enhance navigational efficiency (Brunyé et al., 2014) and most importantly, for the present work, improve performance in visual search tasks (Clark et al., 2012; Falcone et al., 2012; Nelson et al., 2015). Indeed, Clark and colleagues (2012) used fMRI to identify the brain regions involved when participants attempted to identify threats in a series of militarized images. Brain scans were taken as the participants cycled through the threat images, with these scans showing that two regions, the right inferior frontal gyrus (rIFG) and right parietal cortex, were consistently activated in participants as they progressed from novice to intermediate performance. In the next stage of their study, the authors applied tDCS at varying intensities to these two regions during the first half of the threat-detection task (for a period of 25 min). Participants who

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received 2 mA tDCS to the rIFG (F_{10}) or the right parietal cortex (P_4) showed up to 50% greater improvement in accuracy than those receiving 0.6 mA or sham stimulation. Subsequent studies by the same group suggest that this effect of rIFG tDCS may have been due to increases in alerting attention (Coffman et al., 2012) and perceptual sensitivity (Falcone et al., 2012) brought on by tDCS. Such results are consistent with the theorised role of the right inferior frontal cortex in attentional (Chong et al., 2008; Hampshire et al., 2010) and inhibitory control (Aron et al., 2004, 2014), with several other studies also finding improved response inhibition (Jacobson et al., 2011) and regulation (Herrmann et al., 2016) following similar rIFG tDCS protocols. However, tDCS enhancement research has repeatedly faced criticism for its lack of reproducible results due to inadequate methodological designs and limited sample sizes (Hill et al., 2016; Horvath et al., 2016). Further, it has been previously demonstrated that an individual's level of skill and ability can significantly impact their response to paired tDCS and training (Brunyé et al., 2014) thus it remains to be seen if the threat-detection improvements observed by Clark and colleagues (2012) would be observable in a much larger military cohort using a task analogous to their training.

In this pre-registered, large-scale study we expand on the extant literature by exploring whether the significant effects of tDCS to the rIFG would be observed in a cohort consisting of trained military personnel performing a visual search task relevant to their primary role. Although the present study was designed to be an extension, rather than a replication, of previous findings showing positive effects of rIFG stimulation (Clark et al., 2012; Falcone et al., 2012; McKinley et al., 2013) we nonetheless attempted to match stimulation parameters, task difficulty and session schedule as best we could, with the majority of differences in protocol arising from the practical considerations in the use of brain stimulation within military contexts. We also improved upon the ecological validity of the training task through a consultative process with our target population, used double-blinding method for the rIFG conditions, and included an additional control stimulation group. Based on previous findings (Clark et al., 2012; Falcone et al., 2012; McKinley et al., 2013) our primary hypothesis was that anodal tDCS to the rIFG would upregulate the targeted region and thereby lead to increased attentional control resulting in a significant behavioural effect (i.e., increased threat-detection accuracy), and that this effect may be influenced by years of experience and role.

2. METHODS

2.1. Participants

Participants were recruited from two separate units of the Australian Army's Royal Australian Armoured Corps (RAAC) with 98 defence members completing the full study (mean age = 26.5, SD = 4.9, range = 19-42, 6 females). The sample comprised 32 drivers/loaders, 28 gunners, and 38 crew commanders of both armoured fighting vehicles (ASLAV, Boxer) and main battle tanks (M1A1 Abrams). Drivers/loaders, gunners, and crew commands have differing levels of training and experience. In general, drivers and loaders are newer soldiers with <4 years of experience, gunners are more experienced with >4 years of service and more advanced training, and crew commanders are the most trained members of the crew and hold the greatest responsibility for the platform, although age and experience varies more between crew commanders as this role contains both non-commissioned and commissioned officers. We deliberately recruited a cross-section of crew roles to additionally investigate whether soldier experience and level of training influenced task performance.

A tDCS Safety Screening Questionnaire was employed to screen for tDCS contraindications. Specifically, individuals with a family history of psychiatric or neurological condition(s), current psychoactive medication use, significant alcohol or drug use, or recent concussion were excluded from participating in the study. Participants were also provided a written information sheet on the study and given the opportunity to ask any questions before providing informed consent. The Australian Departments of Defence and Veteran's Affairs Human Research Ethics Committee approved all study protocols, and the work was carried out in accordance with Declaration of Helsinki.

2.2. Sample size rationale

We were given support to recruit up to a maximum of 120 volunteers from the Australian Army. We chose to divide this sample into three conditions of $n = 40$ in order to maximise the strength of the study. In determining the sample size we estimated an effect size of Cohen's $d = 1.2$ between active and sham conditions at 1 hour follow-up (Clark et al., 2012; Gibson et al., 2020). Using G*Power version 3.1, we determined that a sample of 34 participants/group would provide 90% power, at an alpha level of 0.05, to detect a smaller effect of Cohen's $d = 0.8$. Subsequent calculations using the BFDA package

(Schönbrodt & Stefan, 2018) in R showed similar results, with 88% of replications terminating at a boundary of $BF_{10} = 6$ for a fixed-n design of $n = 40$ and effect size of Cohen's $d = 0.8$.

2.3. Conditions

Participants were allocated to three stimulation conditions: 2 mA tDCS to the right inferior frontal gyrus ($n = 33$), Sham tDCS to this same site ($n = 34$), and 2 mA to the primary visual cortex ($n = 31$). To ensure balanced representation of roles across the three conditions, participants were assigned to groups based on their role and time of day (AM/PM) using a custom MATLAB script.

2.4. Threat detection task

Our goal when designing this paradigm was to stay as close as possible to the Clark et al. task, while adapting the stimuli for the targeted cohort and the primary task they perform in their military role. This study employed a threat-detection task using images generated with the Australian Army's simulation software, VBS3 (BISim, Australia). The task was programmed and delivered using PsychoPy open-source software (Peirce et al., 2019). Most images (85%) showed a vehicle gunner's view of a complex landscape, with images being either natural light or thermal filtered. 15% of images were from a bird's eye view to simulate the visual feed a soldier may receive from an unmanned aerial vehicle (UAV). There were two reasons for including these aerial images. First, they provided a novel image type for our sample, which was more familiar with the gunner's view. Second, they were more analogous to images used in similar studies exploring training and tDCS on target detection in military personnel (Blacker et al., 2020; McKinley et al., 2013). Half of the images contained a threat/potential target such as an enemy armoured vehicle, tank, or grounded aircraft. Threats were distributed pseudo-randomly (see Fig. 1 E-G) and were between 5 and 10 mm in size. We consulted experienced crew commanders and gunners during the selection of the image sets, to ensure the scenes depicted were relevant to the target population, and that the difficulty of detecting the threats was consistent across images. This experienced cohort were serially presented with the full bank of threat images in an untimed manner and were asked to respond when they identified the threat. We used the median response times to identify images which were too difficult (>5 sec median response time) or too easy (<2 sec median response time). Those images that remained were then used as templates for further image generation. The completed task was then piloted with a small cohort of soldiers ($n = 17$) who did not receive tDCS, to ensure the task ran as intended and that the difficulty level was appropriate for the population. Lastly, we included a post-study survey to capture individual ratings of perceived difficulty and relevance.

As shown in Figure 1A, and similar to Clark et al. (2012), in each trial participants were presented with an image for 3 sec, and required to respond as quickly and as accurately as possible whether or not a threat is present using the "A" or "L" key, with this contingency counterbalanced across participants. In this task there can be one of four outcomes. (1) Misses (target was present but was missed) will evoke negative feedback. (2) Hits (target was present and detected) will evoke positive feedback. (3) False alarm (target was absent but participant indicated it was present) will evoke negative feedback. (4) Correct rejections: participant correctly indicated the absence of a target. Feedback was given via a voice feedback message indicating a correct or incorrect response and the presence/absence of the threat, stating "Identified target," "Target missed," "False alarm, there's no threat here," "No threat, keep scanning." On trials where a threat was present, a box circled the threat during the 5 sec feedback, with a red box indicating a miss and a green box indicating a hit. The images were generated with, and task presented on, 15.6" ASUS ROG laptops.

2.5. Stimulation

A Neuroconn DC Plus stimulator (NeuroCare, Germany) was used to deliver stimulation via two square 25 cm^2 rubber electrodes encased in saline-soaked sponges. The International 10-20 EEG system was referenced for electrode placement. For the experimental group, 25 min of 2 mA anodal tDCS, including 30 sec ramp up and ramp down, was applied via an active electrode on the scalp area overlying the right inferior frontal cortex (F_{10}) in our experimental condition. We localized F_{10} by measuring 10% down from F_8 in line with F_z, with the electrode being centred over the right sphenoid bone. For the sham control group, the F_{10} electrode placement remained the same, with a 30 sec ramp up and ramp down, but with a stimulation duration of only 1 min 15 sec. For the active control group, 25 min of 2 mA anodal tDCS was applied, with the active electrode placed on O_z, which is thought to overlay the primary visual cortex (V1). To locate O_z, the distance from the nasion to inion was measured, and

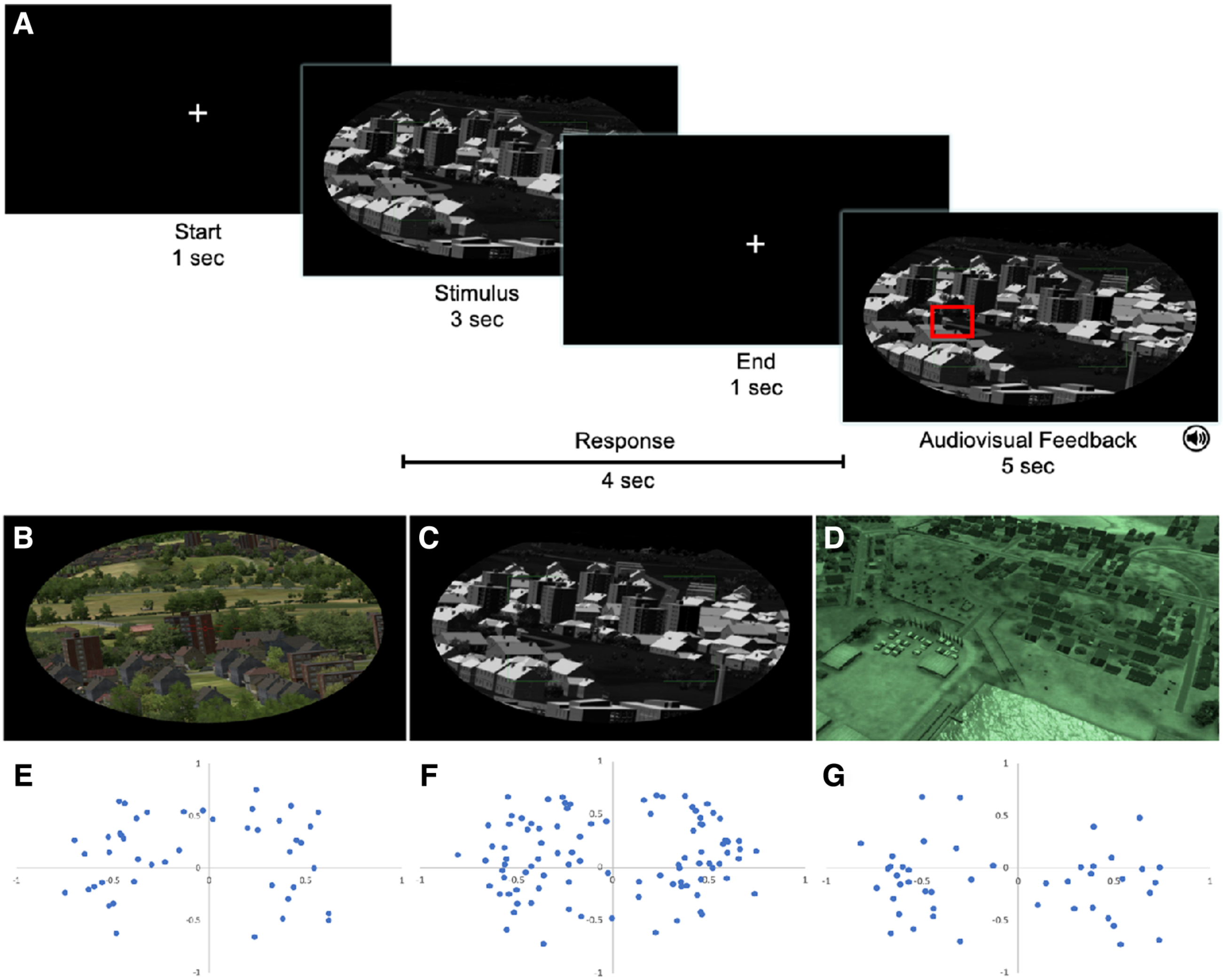

Fig. 1. Threat Detection Task. (A) An example trial of the task. Trials in baseline and test phases did not feature the 5 sec audio-visual feedback. (B) Example of day view image. (C) Example of thermal image. (D) Example of aerial/UAV image. (E) Distribution of threats—Day view. (F) Distribution of threats—Thermal. (G) Distribution of threats—UAV.

then 10% of this total distance from the inion was used, consistent with previous tDCS studies targeting visual cortex (Keogh et al., 2020; Reinhart et al., 2016). Experimenters and participants were blinded to both rIFG conditions using codes supplied by NeuroConn, however, given that our sample was not large enough to also include a sham stimulation V1 group, only the participants were able to be blinded to the V1 condition.

For all groups, a reference electrode of identical size was placed on the (left) contralateral mastoid as a reference electrode. We believed an extracephalic reference electrode would be necessary to show this effect, as a recent study employing a cephalic reference electrode showed no effect of tDCS on this task (Jones et al., 2021).

2.6. Session protocol

The researchers adhered strictly to the session protocol set out in our pre-registration document. For reasons of practicality and timing with such a large cohort, the participants attended the testing room in pairs, with sessions staggered such that a maximum of four participants could be run simultaneously. As previously mentioned, a key component of this study was to extend the findings of previous military-focused studies to an actual military population such that the Australian Defence Force could assess whether this technology holds promise as an intervention. Rarely in the military environment is training undertaken solo, rather group training is the norm, thus our testing environment best reflected the manner in

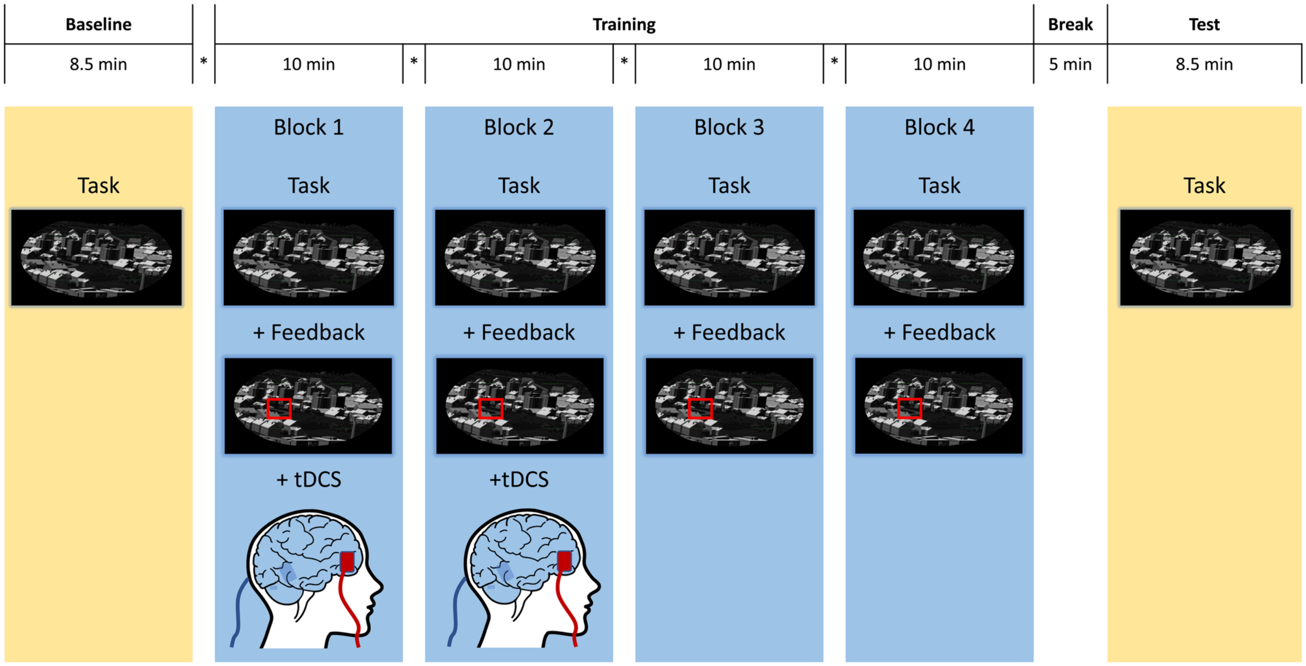

Fig. 2. Session overview. Sessions began with baseline session of 100 trials without feedback, after which electrodes were placed on head and training commenced. Each training block consisted of 60 trials with feedback. Stimulation was administered for 25 min across the first two training blocks with a 2.5 min period of stimulation before the first block, and between the first and second blocks. After a 5 min break, participants completed a final 100 trials without feedback, 50 of these trials using images seen in training, and 50 being novel. * denotes 2.5 min periods.

which tDCS training may in fact be implemented should it prove worthwhile. For this reason, we used a realistic training context where participants were tested in pairs and completed the task in silence (with task feedback provided over headphones), spaced a minimum of 2.5 m apart from each other with strict guidelines enforcing no communication between participants during the task. This contrasts with previous studies which tested university students individually in laboratories (Clark et al., 2012; Falcone et al., 2012).

After completing paperwork and receiving a brief from the researchers, participants underwent head measurement and electrode placement. Sessions began with a ~10 min baseline phase comprising 100 images sans feedback (see Fig. 2). Next, participants performed two training blocks with audio-visual feedback while receiving 25 min of tDCS. A 2.5 min waiting period was imposed at the beginning of stimulation to ensure that the participant felt comfortable with the tDCS and to provide the researchers an opportunity to adjust the electrodes if the impedance was too high. A second 2.5 min break was also placed between training blocks to provide participants a rest. Upon completing the second training block, the tDCS electrodes were removed, and participants completed the final two training blocks without stimulation. After another short break (~5 min) participants then completed a test phase comprising 100 trials sans feedback. In order to examine memory for trained images, and generalization of training to novel images, half of the test images were randomly selected from the training phase images, with the remainder being new to the participant.

3. RESULTS

3.1. Analysis

As per our pre-registered analysis plan, datasets from 98 participants were cleaned and summarised using the *tidyverse* package in R (Wickham et al., 2019). Trials were considered outliers if the response time was below 200 ms or fell outside of the lower (Q1 – 1.5 * IQR) or upper (Q3 + 1.5 * IQR) bounds. Hit and False Alarm rates were also used to produce mean *d'* values for each participant, with this data being further separated by image type (Thermal, Day-view or UAV) and novelty (novel, trained). R output was then analysed using JASP. As described in our pre-registration, we selected both overall accuracy and *d'* as our outcome measures of interest. We used Bayesian analyses comparing training-related gains between the different stimulation groups. Specifically, Bayesian ANOVAs and *t*-tests were conducted to identify between-group differences in performance gains for all dependent variables. In contrast to previous studies which used standard null hypothesis significance testing (NHST), we used a Bayesian approach, which is advantageous as it gives us the ability to not only assess the amount of evidence in favour of an effect of tDCS but also allows us to quantify the amount of evidence in favour of the null. We used the standard interpretation of the resultant Bayes factors (van Doorn et al., 2021), where Bayes factors between 1 and 3 were considered to be weak, Bayes factors between 3 and 10 are considered moderate, and Bayes factors greater than 10 were considered strong evidence for the test hypothesis (BF_{10}) or the null hypothesis (BF_{01}).

3.2. Accuracy

To check homogeneity of groups at baseline, we conducted a Bayesian ANOVA of baseline accuracy scores, with fixed factor being condition and random factors being role, time of day, years of service, and age. This analysis revealed moderate evidence for an absence of effect of condition at baseline (BF_{01} = 5.693). Performance gains, as quantified via the change from baseline to test in both mean accuracy scores and *d*', were subjected to Bayesian ANOVAs and planned *t*-tests, as per our pre-registered analysis plan. Bayesian ANOVAs revealed substantial evidence for an absence of an effect of stimulation condition on both accuracy change scores (BF_{01} = 6.594; see Fig. 3A-B) and *d*' change scores (BF_{01} = 5.633; see Fig. 3C) between conditions. These results held with or without the addition of covariates such as age, role, time of day, and image type. Although Hit rates appeared to trend higher in the rIFG Active condition at baseline, a Bayesian ANOVA revealed moderate evidence against a difference between conditions (BF_{01} = 3.128; see Fig 3E). We also conducted planned Bayesian independent samples *t*-tests comparing Active rIFG and Sham rIFG conditions, as per our pre-registration, and found no evidence of a significant difference in mean accuracy change scores (BF_{01} = 3.872) or *d*' change scores (BF_{01} = 2.218). Learning was evident across all groups, with higher rates of accuracy for trained images compared to novel images at test, but with no significant difference between conditions. Both sham and active rIFG conditions reached 78%, and the V1 condition 79%, on trained images, compared to accuracy levels of 68% for the sham rIFG and 69% for both active conditions on novel images.

3.3. Response time

Bayesian ANOVA on change in response time from baseline to test revealed moderate evidence for no significant effect of condition on response times (BF_{01} = 3.534; see Fig. 3D).

3.4. Post-study survey

We obtained the participants ratings of task relevance, difficulty, and performance using an online survey administered post-study (see Figure S2). On a scale of 1--5 with 1 being *very relevant* and 5 *not relevant at all,* most participants rated relevance as a 1 (35.1%) or 2 (39.1%). Most responses for both perceived task difficulty (51.5%) and self-rated performance (55.7%) were a middling score of 3. Regarding blinding, only 24 of the 97 respondents correctly guessed their stimulation condition, with 18 being unsure and 55 incorrect. After excluding "Unsure" responses, we had strong evidence that subjects were not greater than chance at correctly guessing the sham condition (BF_{0+} = 14.403), and anecdotal evidence that subjects were not greater than chance at correctly guessing the active condition (BF_{0+} = 2.098).

3.5. Electric field modelling

Electric field modelling of our experimental condition montage using a standard head model in simNIBS 4.0.1 (Thielscher et al., 2015), an open-source software application that utilises the finite element modelling method, revealed estimated current concentrations primarily peaked in the rIFG, with lesser concentrations observed in the right temporal lobe (see Fig. 4). Thus, this is consistent with our protocol successfully targeting the desired brain region.

4. DISCUSSION

Previous studies have shown that tDCS to the rIFG improved naïve participant performance in militarised threat-detection task (Clark et al., 2012; Falcone et al., 2012; McKinley et al., 2013). We extended upon these studies using a similar task and tDCS protocol in a trained

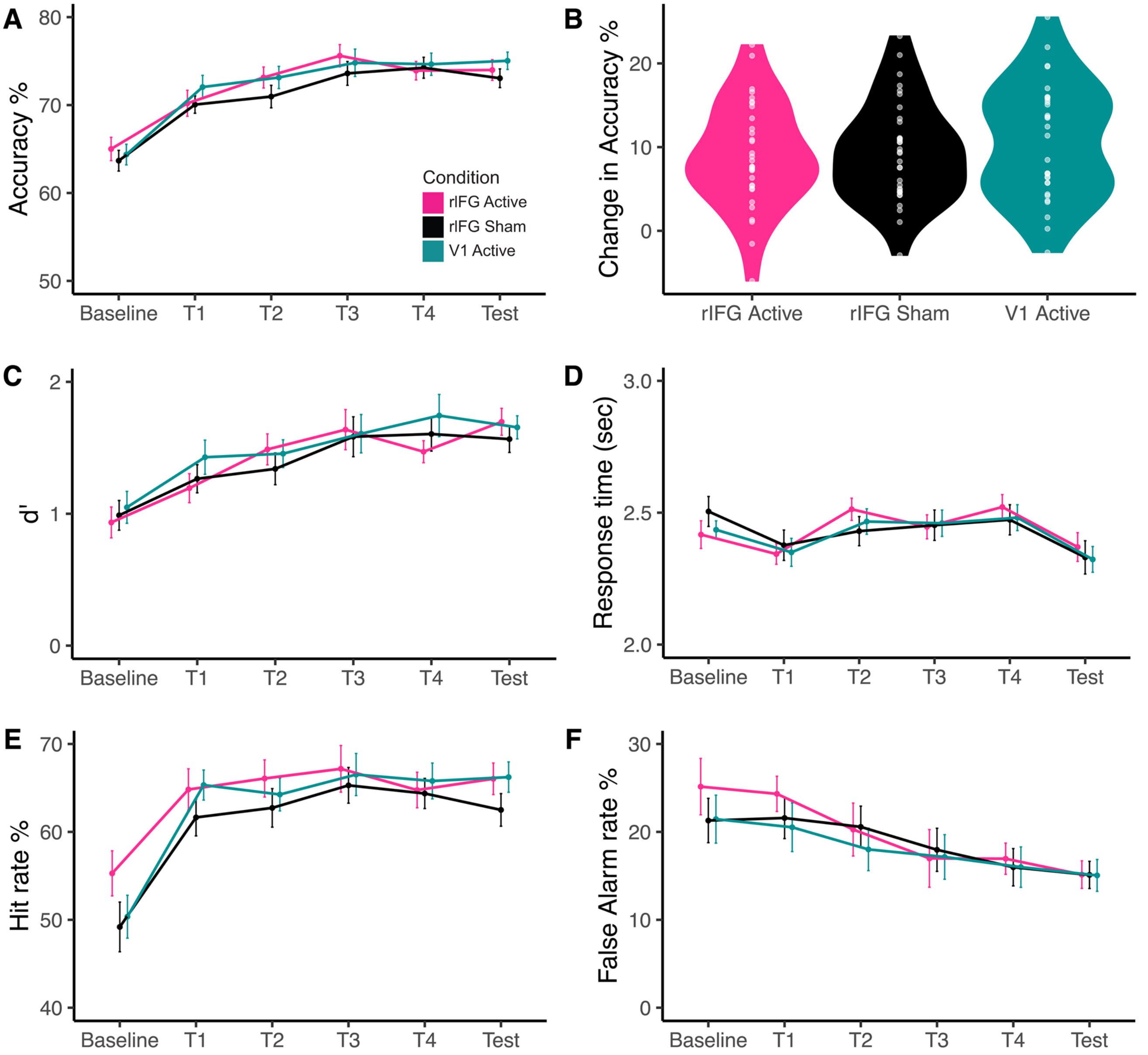

Fig. 3. Task Data (A) Overall accuracy across training. (B) Changes in Accuracy between Baseline and Test (C) d' across training. (D) Response time across training. (E) Hit rates across training. (F) False Alarm rates across training.

military sample and found evidence against an effect of 2 mA in the right inferior frontal gyrus tDCS on performance. There are numerous reasons why the previous findings were not reproduced here as discussed below.

4.1. tDCS

It must be noted that while highly similar in approach, there exists notable differences in the tDCS protocol employed in the present study compared to previous work. First, we used a 25 cm^2 wet-sponge electrode resulting in an estimated current density of 0.08 mA/cm^2, whereas previous studies of this nature estimated their current densities to be between 0.18 and 0.19 mA/cm^2 (Clark et al., 2012; Falcone et al., 2012; McKinley et al., 2013). This choice was made as we have previously achieved significant effects with this larger electrode size in visual search tasks, using lower current densities than the present study (Filmer et al., 2017). Further, instead of using an extracephalic reference electrode on the left triceps, we chose the contralateral mastoid, similar to our previous work (Nydam et al., 2020). We preferred the contralateral mastoid reference

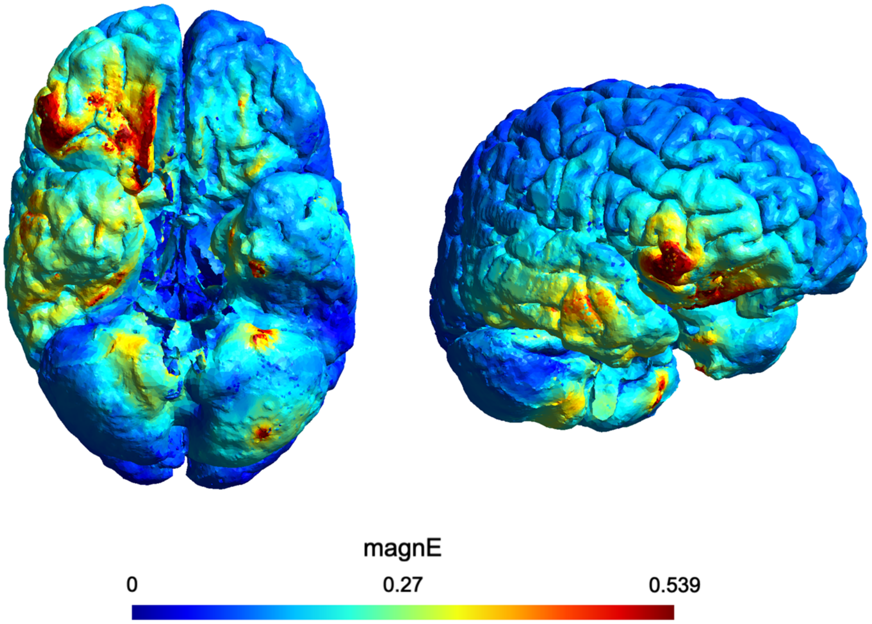

Fig. 4. Electric Field Modelling. Modelling of the experimental condition (2 mA to rIFG) shows peak estimated current concentrations in the inferior frontal gyrus, with weaker concentrations in surrounding areas including the right temporal lobe.

electrode for the following reasons: (1) Electrode placement on the left triceps limits movement of the left arm during military training, which limits potential utility and/or uptake of this stimulation protocol. (2) Longer distances between active and reference electrodes might reduce the potency of tDCS stimulation, as studies measuring the effects of tDCS on motor-evoked potentials show that the longer the distance between the active and reference electrodes, the less persistent was the effect of tDCS on motor-evoked potentials (Moliadze et al., 2010). Although much closer to the active sites, the mastoid is an extracephalic location and should avoid the issues seen in the previous work where bicephalic sites were used (Jones et al., 2021).

While EF modelling showed the rIFG to be the focal point of our tDCS montage, it is possible that the decreased distance between the active and reference electrode, coupled with the larger electrode size may have influenced the behavioural outcome. For example, a previous study using a protocol similar to Clark et al. (2012) found no behavioural effect of tDCS when applying a weaker dosage (1 mA) to the P_4 target site using a larger electrode (35 cm^2) despite significant differences in resting state brain activity being observed in the stimulation condition compared to sham (Callan et al., 2016). Further, although weaker tDCS montages directed at the rIFG have resulted in significant attention improvements, these montages involve multiple sessions (Breitling-Ziegler et al., 2021). Thus, our rIFG tDCS montage applied in a single session may not have reached the critical threshold for observable behavioural change as seen in previous studies (Clark et al., 2012; Falcone et al., 2012; McKinley et al., 2013) and future work may need investigate the optimal tDCS dosage required to elicit an effect with this type of electrode placement, as was done in Clark et al. (2012) and our own previous work (Ehrhardt et al., 2022). However, as we were unable to obtain imaging data of our participants, any inference we make regarding our stimulation parameters and their effect on the target brain areas is limited. An additional note is that this study did not include a control group who received no stimulation. It has previously been suggested that sham tDCS can elicit similar task improvements as active stimulation relative to an electrode-free control group when using military personnel (McKinley et al., 2013). Similarly, placebo effects have also been observed in EEG measures of brain activity during sham stimulation (Petersen & Puthusserypady, 2019). Thus, it is possible that the novelty of electrodes attached to the head in our sham and site control conditions influenced performance via placebo effect, thereby obfuscating any real effect.

4.2. Task

We designed a new task for this study rather than re-use the task from Clark et al. (2012), due to several factors, including access to original stimuli and applicability to our target population. As such, there are key differences between the tasks that may influence the results. For example, the original task had participants learn to identify certain ambiguous cues that predicted a negative outcome (Clark et al., 2012; Falcone et al., 2012). Ambiguous cues are valid for dismounted soldiers, as they patrol areas on foot and come in close contact with the suspect objects, but our sample comprised personnel whose primary visual search task is to determine the location and range of enemy combatant vehicles. Thus, our task featured much more easily identifiable threats, albeit placed at a greater distance from the viewer. Further, while we provided auditory feedback, we opted to highlight the threat location rather than use video feedback as was done in the original. These differences in the nature of the stimuli and the feedback may have influenced the difficulty of the task, as well as the type of learning occurring. However, it should be noted that the task used in the present study not only had the stimuli vetted by subject matter experts but was also piloted with a sample of the target population prior to data collection commencing. This contrasts with other studies of this nature where the difficulty of the stimulus was only vetted internally by the research team (Clark et al., 2012; Falcone et al., 2012). Although, as we did not conduct fMRI in our study, it is also not possible to discern whether the same regions were active in our task as they were in these aforementioned studies. But given the relatively diffuse nature of tDCS (Filmer et al., 2020) and the positive findings in similar studies (McKinley et al., 2013), one can reasonably expect some overlap in regions between the two tasks.

4.3. Population

Lastly, in interpreting the results of the present study, we also need to consider possibly the most important factor, that being the populations from which each study drew its sample. Very few tDCS studies have used active-duty military personnel, and of those that have, none have recruited as large a sample as the present study (Brunyé et al., 2014; McIntire et al., 2017; McKinley et al., 2013; Nelson et al., 2016). Thus, the results presented here represent one of the larger studies of this nature to have been undertaken with an active-military population and provides valuable insights into how differently this population interacts with militarised visual search tasks. As an example, in comparing our behavioural data to that of previous papers, we saw that overall accuracy and hit rates across the session were very similar to previous studies, but false alarm rates were much lower in the military sample, with initial rates almost half that of the civilian sample (Falcone et al., 2012). This lower false alarm rate of course influenced the *d*' scores, with all conditions in the military cohort reaching an average *d*' equal to that of the experimental group in Falcone et al. (2012). This suggests that the soldier participants may have been more hesitant to respond that a threat was present without being able to precisely identify the threat. Such behaviour would be consistent with their military training, where rapid image identification tasks which prioritise accuracy are used extensively as both measures of competency and as barrier tests for promotion. Such an interpretation is supported by recent evidence where tDCS was found to have no effect on performance, as participants underwent training on two separate image search strategies (Blacker et al., 2020). Further, a follow-up study to Falcone et al (2012) found that participants with a high level of experience in first-person-shooter videogames, not dissimilar to simulated militarised marksmanship training, demonstrated levels of performance similar to those who received 2 mA tDCS in previous studies (Falcone & Parasuraman, 2012). Thus, we argue that the lack of an effect of tDCS in the present study may be primarily explained by the prior experience of the sample, namely military training.

5. CONCLUSION

Previous research has demonstrated that anodal tDCS to the rIFG may enhance the learning and performance of naive participants in militarised visual search tasks (Clark et al., 2012; Coffman et al., 2012; Falcone et al., 2012; McKinley et. al., 2013). However, these results were not reproduced in a trained military sample. While it is possible that modifications in methodology discussed contributed to this null result, the most parsimonious explanation is that inherent differences between the populations sampled, namely the level of skill and training, may explain the contrasting results. In summary, the results of the present study highlight the importance of considering both the expertise of the sample and context of the task when conducting military-focussed research in this area.

DATA AND CODE AVAILABILITY

All task and participant data remain the property of the Australian Department of Defence and may not be accessed without express permission from the authors.

Task related files and data are hosted on OSF with access available on request. Pre-registration can also be viewed on OSF; https://doi.org/10.17605/OSF.IO/R794X.

AUTHOR CONTRIBUTIONS

Nicholas S. Willmot: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data collection, Data curation, Visualization, Project administration, Writing—original draft. Li-Ann Leow: Conceptualization, Methodology, Investigation, Data collection, Visualization, Writing— review & editing. Hannah L. Filmer: Conceptualization, Methodology, Funding acquisition, Writing—review & editing. Paul E. Dux: Conceptualization, Methodology, Funding acquisition, Writing—review & editing.

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DECLARATION OF COMPETING INTEREST

The authors declare no competing interests.

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SUPPLEMENTARY MATERIALS

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