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EEG correlates of neutral working memory training induce attentional control improvements in test anxiety

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ABSTRACT

Attentional control theory states that high test anxious (HTA) individuals suffer from impaired attentional control. However, through working memory training it may be possible to improve such individuals' attentional control ability. This study investigated whether 20 days of working memory training (with emotionally neutral stimuli) does result in improved HTA individuals' attentional control ability. Pre- and post-outcomes of attentional control were measured using Flanker and Go/Nogo experimental tasks in a test-related stress situation, and EEG data were also collected. Results only showed a significant decrease in Nogo alpha power in HTA individuals after neutral working memory training (i.e., post-outcome versus pre-outcome). However, we failed to provide evidence for beneficial transfer effects of neutral working memory training on enhanced task performance in both the Flanker and the Go/Nogo tasks. So, the present study demonstrates that neutral working memory training is clearly associated with important neurophysiological correlates while performing the Go/Nogo task, but the transfer effect is rather limited.

1. Introduction

To date individuals in society have to cope with an age characterized as the "age of stress" or the "age of anxiety" (Bayram & Bilgel, 2008; Zeidner, 1998). Test anxiety in individuals refers to a situation-specific form of anxiety, with anxiety-related cognitive, behavioral, and affective characteristics elicited by test-related stimuli, especially stimuli referring to educational or evaluative settings (Zeidner, 1998). Test anxiety manifests itself as a considerable anxiety problem in student populations. For instance, a recent meta-analysis examining the Chinese student population indicates that about 22% of students exhibit high levels of test anxiety (Huang & Zhou, 2019). As opposed to individuals exhibiting low levels of test anxiety (LTA), individuals exhibiting high levels of test anxiety (HTA) often experience more emotional and learning problems. HTA individuals are more likely to allocate attentional control resources to threatening stimuli implying that, when being confronted with a threatening stimulus, the remaining and thus available attentional control resources tend to be reduced (Eysenck, Derakshan, Santos & Calvo, 2007). Past research has demonstrated that HTA individuals exhibit attentional control deficits leading to reduced ability of inhibition (Wei, De Beuckelaer, & Zhou, 2021; Wei, Oei, & Zhou, 2022; Wenpei, De Beuckelaer, Lirong & Renlai, 2019; Zhang, Zhou, & Zou, 2015).

In recent years, a highly debated research topic is on how to improve attentional control ability in high anxious or worried individuals, a broader category which includes test anxious individuals. Evidence supports that individuals' attentional control is related to working memory which enables an individual to hold information in the mind and mentally "manipulate" that information (Diamond, 2013). As, in general, the amount of working memory is limited, individuals' attentional resources are always scarce (Lavie, Hirst, De Fockert & Viding, 2004; Wei & Zhou, 2020). Recent studies showed that working memory training incorporating emotional materials exhibit stable effects, in particular an improvement of attentional control ability in high anxious individuals (Lotfi, Ward, Ayazi, Bennett, Larson & Lee, 2021; Minihan, Samimi, & Schweizer, 2021). However, as explained further on, the

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improvement of attentional control ability in high anxious or worried individuals as demonstrated in experimental studies in which neutral materials were used to examine the effects of working memory training cannot be regarded as stable effects (Hotton, Derakshan, & Fox, 2018; Sari, Koster, Pourtois & Derakshan, 2016; Zhao, Dang, & Maes, 2020). Working memory training making use of neutral materials is from now on referred to as "neutral working memory training". Indications of improved attentional control in high anxious or worried individuals are found in several experiments. More particularly, several experiments suggested beneficial effects of neutral working memory training. First, making use of a Flanker task in a noise stress condition and the monitoring of resting state electroencephalography (EEG, i.e., theta/beta power ratio) Sari et al. (2016) found that found that 15 days of adaptive neutral working memory training improved high trait anxious individuals' attentional control ability. Second, using a color word Stroop task Hadwin and Richards (2016) found that 25 days of Cogmed working memory training improved high anxious individuals' attentional control ability. Third, using an Antisaccade task Course-Choi, Saville, and Derakshan (2017) found that 7 days of adaptive neutral working memory training improved task performance in individuals exhibiting high levels of worry. Fourth, using a Go/Nogo task Minihan et al. (2021) found that 20 days of adaptive neutral working memory training improved task performance in HTA individuals.

Unfortunately, as mentioned before, the stability of these experimental results may be questioned. First of all, three out of the four experimental studies cited above (the exception is Sari et al. (2016)) did not work with an effective "active" control group for assessing the effects of neutral working memory training. As a consequence, we cannot fully exclude the possibility that the beneficial effects of neutral working memory training found are due to some single confounding factor or, alternatively, multiple confounding factors, such as a "placebo effect", a "practice effect", and so on. In addition, other experimental studies have also provided partial evidence against the idea of neutral working memory training-related beneficial improvements on attentional control ability in high anxious or worried individuals. First, the experimental study by Sari et al. (2016) also concluded that, despite the higher mentioned improvements in a noise stress condition observed only in the Flanker task, no such improvements were observed in a no noise stress condition in both the Flanker and the Antisaccade tasks. Second, another experimental Flanker task study by Hotton et al. (2018) found that 15 days of adaptive neutral working memory training failed to enhance experimental task performance in individuals exhibiting high levels of worry. Third, an additional experimental, color word Stroop task study by Zhao et al. (2020) found that 20 days of adaptive neutral working memory training did not enhance experimental task performance in individuals exhibiting high levels of social anxiety.

The mixed experimental results pointing in opposite directions amongst high anxious or worried individuals, and possible problems with confounded effects (due to an ineffective, i.e. inactive control group) gave rise to the question as to that whether or not high anxious or worried individuals' attentional control ability can be improved through neutral working memory training. In the present study which relies on neutral working memory training we present our experimental results indicating whether reduction or elimination of impaired attentional control ability is likely in HTA individuals.

In order to derive such indication the present study first identified two main reasons as to why the experimental results on high anxious or worried individuals are mixed. Firstly, the higher cited experimental studies were based on experimental designs that varied in terms of the "inhibition task" presented to the high anxious or worried individuals. Inhibition as a concept may be decomposed in two components or processes, namely interference suppression and prepotent response inhibition (Friedman & Miyake, 2004). The first process, interference suppression, concerns individuals' ability to control for distracting experimental stimuli or the presentation of task-irrelevant and thus redundant stimuli. To invoke interference suppression experimental studies, like the ones cited above, make use of a variety of experimental tasks, including a Flanker task, a word naming task and a Simon task (Friedman & Miyake, 2004; Velzen, Chris, Wit, & Heuvel, 2014). The second process, prepotent response inhibition, concerns the suppression of a prepotent or automatic behavioral response. To invoke prepotent response inhibition experimental studies, like the ones cited above, also make use of various experimental tasks, in particular: a Go/Nogo task, a Stop signal task, and a color word Stroop task (Friedman & Miyake, 2004; Velzen et al., 2014). The variety in experimental tasks across studies also implies that these studies differ substantially in terms of experimental task complexity. In other words, across these studies: (1) unequal demands on attentional control resources are imposed, and/or (2) different inhibition processes are invoked (Brydges et al., 2012; Friedman & Miyake, 2004; Sebastian et al., 2013). In addition, even within the same experimental study, experimental situations may be highly variable. For example, Sari et al. (2016) found that neutral working memory training only improved Flanker task performance in just one experimental situation, namely the noise stress condition, but failed to improve Flanker task performance in the no noise stress condition. Also Hotton et al. (2018) found that neutral working memory training failed to improve Flanker task performance. In sum, existing experimental studies typically suffer from imbalances in the experimental design, possibly leading to biased experimental findings, in particular the finding that neutral working memory training only improves Flanker task performance in a noise stress condition and not in a no noise stress condition. Our experimental study avoids biased experimental findings by relying on a more balanced experimental design which includes both a Flanker task and a Go/Nogo task, a combination of experimental tasks which allows fully controlling the experimental situations across the experimental conditions.

Importantly, some existing experimental, Flanker task studies (Hotton et al., 2018; Sari et al., 2016), Stroop task studies (Hadwin & Richards, 2016) and Antisaccade task studies (Course-Choi et al., 2017) examined impaired attentional control only at the behavioral level and not at the neurophysiological level. In order to provide an improved measurement of individuals' attentional control ability and extend earlier experimental work with an exclusive focus on behavioral measures, we designed our experimental study such that it assesses attentional control at both the neurophysiological and the behavioral levels. As already mentioned above, notable exceptions of existing experimental studies that did assess impaired attentional control at both the neurophysiological and the behavioral levels are Sari et al. (2016) who relied on an Antisaccade task, and Zhao et al. (2020) who relied on a color Stroop task. These "exceptional studies" (Sari et al., 2016; Zhao et al., 2020) only used the event-related potential (ERP) index to reflect brain's EEG activity that is time- and phase-locked to the onset of a stimulus or a behavioral response. It has already been shown that event-related spectral perturbation (ERSP) which is adequately assessed by only time- (and thus not phase-) locking to the onset of a stimulus or response may, at least potentially, reveal novel neurophysiological mechanisms that are involved in attentional control process (Makeig, Debener, Onton & Delorme, 2004).

For our experimental study which aimed at assessing test anxious individuals' attentional control we relied on both a Flanker and a Go/Nogo task, while both ERP and ERSP data were analyzed. In a Flanker task, compared to the congruent trials, the incongruent trials are associated with larger N2 amplitude in the frontal and central regions and smaller P3 amplitude in the parietal region (McDermott, Wiesman, Proskovec, Heinrichs-Graham & Wilson, 2017; Tillman & Wiens, 2011; Wei & Zhou, 2020). In a Go/Nogo task, compared to the Go trials, the Nogo trials are associated with larger N2 amplitude in the frontal and central regions and larger P3 amplitude in the parietal region (Falkenstein, Hoormann, & Hohnsbein, 1999). Both the Flanker and the Go/Nogo related N2 amplitude are often conceived as an important indicator of conflict monitoring, that is they may reflect attentional control processes used to focus attention on task-relevant aspects of an experimental situation (Folstein & Van Petten, 2008; Righi, Mecacci, & Viggiano, 2009; Sehlmeyer, Konrad, Zwitserlood, Arolt, Falkenstein & Beste, 2010; Tillman & Wiens, 2011). Additionally, the Flanker related P3 amplitude is often conceived as an important indicator of later attention processing, reflecting working memory demands and it is modulated by task difficulty (Polich, 2007; Pratt, Willoughby, & Swick, 2011; Wei & Zhou, 2020); the Nogo P3 amplitude is also conceived as an important indicator of later attention processing, that is it may reflect the monitoring of the outcome of inhibition or motor inhibition (Sehlmeyer et al., 2010; Smith, Johnstone, & Barry, 2008; Zordan, Sarlo, & Stablum, 2008).

In addition, existing studies have shown that, in the Flanker task, compared to congruent trials, the incongruent trials are associated with increased theta power in the frontal and central regions. In the Go/Nogo task, compared to the Go trials, the Nogo trials are also associated with increased theta power in the frontal and central regions (Brier et al., 2010). The increased theta power in the frontal and central regions may indicate a necessity to recruit other prefrontal areas when more cognitive control resources are required to complete an experimental task (Cavanagh & Frank, 2014; Nigbur, Cohen, Ridderinkhof & Stürmer, 2012; Pastötter, Dreisbach, & Bäuml, 2013). Existing studies have also shown that, in the Flanker task, evidence points into the direction of either an increase or a decrease in alpha power for incongruent trials in the parietal region when compared to congruent trials (Gonzalezvillar & Carrillodelapena, 2017; Wei & Zhou, 2020). In the Go/Nogo task, compared to the Go trials, the Nogo trials are associated with decreased alpha power in the parietal region (Brier et al., 2010; Lydon, Nguyen, Shende, Chiang, Spence & Mudar, 2022). Existing studies showed that, a decrease in alpha power may reflect an individual's increased attention to the current task, whereas an increase in alpha power may reflect inhibition of those posterior regions not required for the task (Händel, Haarmeier, & Jensen, 2011; Jensen & Mazaheri, 2010; Klimesch, Sauseng, & Hanslmayr, 2007; Pfurtscheller, Stancak Jr, & Neuper, 1996; Van Gerven & Jensen, 2009).

Based on the existing literature and our reasoning presented above we designed our experimental study as follows. In the pre-training and post-training sessions, HTA individuals were asked to complete the test anxiety scale (TAS), and perform both the Flanker and the Go/Nogo tasks, while the collected ERP and ERSP data were analyzed. As test anxiety is a situation-specific form of anxiety, the individuals completed the TAS and tasks in a test-related stress situation. Individuals belonging to the working memory training group were asked to complete the adaptive running working memory task five days per week (once a day, in an available time slot) during one month; individuals belonging to the control group were asked to complete an easy working memory task five days per week (once a day, in an available time slot) during one month. The adaptive running working memory was already found to enhance individuals' working memory ability (Chen, Ye, Chang, Chen & Zhou, 2018; Xiu, Wu, Chang & Zhou, 2018; Zhao, Wang, Liu & Zhou, 2011; Zhao, Zhou, & Fu, 2013).

In terms of predicted outcomes of our experiment we made the following two predictions. Our first prediction was that, in both our Flanker and Go/Nogo experiments, the neutral working memory training improves HTA individuals' attentional control ability as indicated by enhanced task performance observed at both behavioral and neurophysiological levels. Our second prediction was that, neutral working memory training transfer effects are associated with the reduction in the level of test anxiety. The reason for our second prediction is obvious: previous studies demonstrated that neutral working memory training may reduce individuals' anxiety symptoms (Beloe & Derakshan, 2019; Zhao et al., 2020).

2. Methods

2.1. Participants

The power analysis for the present study was based on what was done previously in Zhao et al. (2020). We specified as input for the statistical power analysis of a two-group experimental design: (1) an expected effect size of $f = 0.25$; (2) a required statistical power level of $1\text{-}\beta = 0.80$; (3) $\alpha = 0.05$; and (4) an assumed correlation coefficient between repeated measures of $r = 0.5$, one should rely on a minimal group sample size as large as 17 individuals (computations were made by the software: G*Power 3.1.9.2, test family: F tests, statistical test: ANOVA: repeated measures, within-between interaction). Participants were recruited from Nanjing University in P.R. China. Initially, a total of 580 students took part in a mass screening. Subsequently, 170 participants who scored high on test anxiety (TAS score > 20) were further considered for being selected as participants. However, after being informed of the experimental procedures (e.g., the need for using a shampoo to collect EEG data, 22 consecutive visits to the lab) a substantial number of potential participants indicated they did not consider starting with the experiment. Eventually, a total of 69 HTA participants were selected, and participants were randomly assigned either to the training ($n = 35$) or the control ($n = 34$) groups. All participants gave their written informed consent and were informed about their right to discontinue participation at any time. Practical issues led to the unavailability of data related to 22 participants. Such practical issues included participants who did not manage to timely complete the working memory training task, then gave up halfway through the experiment (13 participants), and EEG data which turned out to be unusable (due to a machine failure; 9 participants). Eventually, usable data on 47 participants were collected; 21 participants (mean age = 20.62 ± 1.88 years, 15 females) formed the "training group" and 26 participants (mean age = 19.80 ± 1.66 years, 20 females) formed the "control group" (see Fig. 1). The experimental procedures were approved by the Ethics Committee of the Department of Psychology, Nanjing University and carried out in accordance with the approved procedures.

2.2. Pre- and post-measures

2.2.1. Test anxiety

The group of participants suffering from test anxiety was formed based on participants' score on the Chinese version of TAS (C. Wang, 2001; Wei et al., 2021). In line with conceptual underpinnings of the concept of test anxiety (Sarason, 1977), and in accordance with Newman (Newman, 1996), those participants scoring > 20 on TAS were assigned to the HTA group.

2.2.2. Flanker task

An adapted 'arrow version' of the Flanker task was implemented (Wei & Zhou, 2020). As shown in Fig. 2a, in every experimental trial, the following 3-step sequence was programmed: (1) step1, start of the experimental trial: a fixation cross in the middle of the computer screen was displayed for 300 ms; (2) step 2, a blank screen was shown for 1000–1500 ms (randomized); (3) step 3, stimulus presentation: the five arrows jointly composing the Flanker task were presented on the screen for 300 ms, including one centrally positioned target arrow and two flanked distractor arrows on each side (left and right) of the target arrow. In step 3, two different experimental conditions were imposed for the experimental trial: (1) in the congruent condition (50% chance, at random), the target arrow and the distractor arrows were in the same direction (i.e., same orientation), and (2) in the incongruent condition (50% chance, at random), the target arrow and distractor arrows were in the opposite direction (i.e., opposite orientation). Participants were instructed to indicate as quickly and accurately as possible the direction of the target arrow and press on the computer keyboard a button "F" if

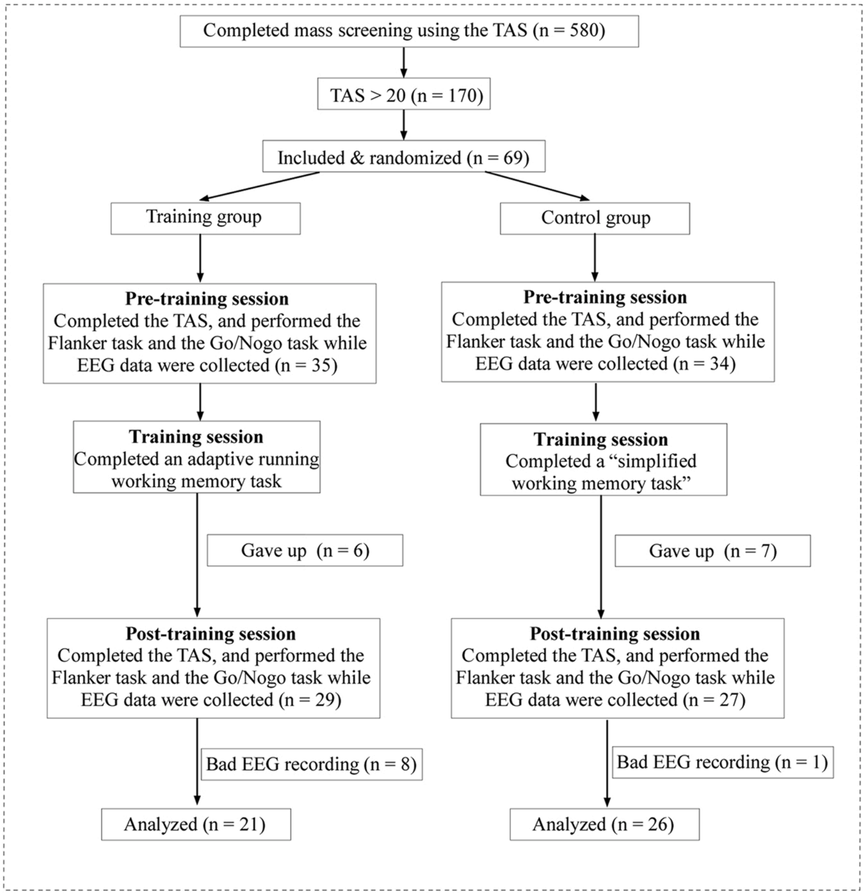

Fig. 1. Study flowchart. Note: TAS, test anxiety scale.

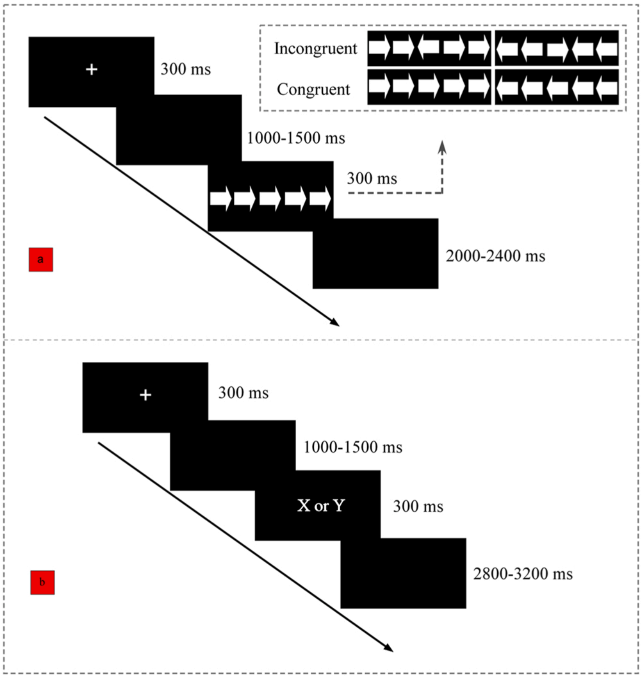

Fig. 2. a. Schematic representation of the Flanker task; Fig. 2b. Schematic representation of the Go/Nogo task.

the target arrow pointed to the left or a button “K’’ if the target arrow pointed to the right. Each arrow subtended a visual angle of 0.6° vertically and 0.8° horizontally. The distance between the arrows was 0.16°. The inter-trial interval was 2000–2400 ms (randomized). All the stimuli were white and appeared on a black screen. The experiment consisted of three blocks, and participants had a three-minute break between consecutive blocks. Each block consisted of 88 congruent trials and 88 incongruent trials.

2.2.3. *Go/Nogo task*

An adapted ‘letter version’ of the Go/Nogo task was implemented (Sehlmeyer et al., 2010). As shown in Fig. 2b, in every experimental trial, the following 3-step sequence was programmed: (1) step1, start of the experimental trial: a fixation cross in the middle of the computer screen was displayed for 300 ms; (2) step 2, a blank screen was shown for 1000–1500 ms (randomized); (3) step 3, stimulus presentation: the letter “X” (75% chance, at random) or “Y” (25% chance, at random) was presented for 300 ms. Participants were asked to press on the computer keyboard a button “space”, as quickly and accurately as possible, a button when “X” is shown, but to withhold their response when “Y” is shown. The letter “X” or “Y” was presented with a visual angle of 0.6° vertically and 0.8° horizontally. The inter-trial interval was 2800–3200 ms (randomized). All the stimuli were white and appeared on a black screen. The experiment consisted of two blocks, and participants had a three-minute break between the consecutive blocks. Each block consisted of 120 Go trials with the letter “X” and 40 Nogo trials with the letter “Y”.

2.3. *Working memory training task*

2.3.1. *Training group*

To ensure the duration of participants' daily neutral working memory training was substantial and to avoid boredom due to repeating the same version of working memory training, participants in the training group were instructed to complete an adaptive running working memory task, which included three different versions: 'animal', 'letter' and 'location'. Participants had to complete, once in every training day, sequentially the three computerized self-adaptive training programs: 1. 'animal', 2. 'letter' and 3. 'location'. For example, in the animal version, different animals were presented sequentially in the center of the computer screen. In each trial the number of animals randomly varied between 5, 7, 9, and 11, numbers which are chosen such that they create sufficient variation across trials. Participants were told to remember the last three animals presented in the trial. After the 5, 7, 9 or 11 animals were presented a "memory probe" registered the selection of three animals the participant indicated as being presented at the very end. The memory probe ended when the participant finished making his/her selection. Every training day, participants needed to complete 30 trials that were separated into six blocks of five trials each. Each item (e.g., animal) was presented for 1750 ms. The item presentation time in the next block would drop by 100 ms if participants correctly completed three or more trials in the present block. However, if participants correctly completed, in the present block, just two trials or just one trial item presentation time in the next block would increase by 100 ms. The item presentation time of the next day's training day was set identical to the last block's item presentation time (on the previous day). The letter and location version were completely analogous to the animal version, but, in these versions, different locations and different letters were shown. No strict time limit was set for training. Participants spent about 30 min a day completing the training at the beginning, and about 20 min in the last training day. As we replicated the experimental procedures followed by previous studies (Chen et al., 2018; Xiu et al., 2018; Zhao et al., 2011), we refer to Zhao et al.'s study (Zhao et al., 2011) to inform the reader about experimental details related to the three versions of the adaptive running working memory task.

2.3.2. *Control group*

To avoid an experimental failure, in particular: a placebo effect (leading to an experimental confound compromising the validity of our experimental results), participants in the control group also needed to be "active", that is they had to complete a "simplified working memory task". They needed to complete 90 trials of a simplified animal working memory task every training day during five days a week. An experimental trial was sequenced as follows: first, an animal was presented in the center of computer screen which was displayed for 1750 ms; second, a memory probe started with 9 different animals presented as choice options, participants were required to select out of these choice options the last animal presented. The memory probe ended when the participant finished his/her selection. Because of the simplified nature of this working memory task participants were asked to complete it as quickly as possible. Participants spent about 10 min a day completing the training.

2.4. *Procedure*

Participants were seated comfortably in separate rooms about 70 cm away from a 21-inch computer screen. The formal experiment consisted of three parts: pre-training session, training session and post-training session. First, participants were invited to complete the pre-training session and were grouped as training and control groups. Second, after the pre-training session, participants needed to complete the working memory training task five days per week (once a day, in an available time slot) during one month. Third and last, after about one month, participants needed to complete the post-training session. In both the pre- and post-training sessions, participants completed the TAS, and performed the Flanker task and the Go/Nogo task while EEG data were collected. As test anxiety is a situation-specific form of anxiety, previous studies have demonstrated that HTA individuals show more attentional control deficits in a test-related stress situation than LTA individuals (Wei et al., 2021). So, prior to the pre-training session and post-training session, participants were informed that: (1) the aim of the project was to measure cognitive ability; (2) the experimental task assesses level of intelligence and can be used to predict educational performance outcomes; and (3) personal results will be evaluated by members of the departmental teaching staff and compared with the results of other participants. By providing this information in the specific experimental context participants were expected to be stressed (Keogh & French, 2001; Putwain, Langdale, Woods & Nicholson, 2011; Wei et al., 2021). Finally, the participants were debriefed after the post-training session.

2.5. *EEG data collection and analysis*

EEG data were collected using 32 Ag-AgCl scalp electrodes placed according to the International 10–20 system (pass-band: 0.01–100 Hz; sampling rate: 500 Hz). The signals were amplified using Neuroscan NuAmps amplifiers (22-bit resolution). Prior to recording, impedances were below 10 kOhm. During recording, the ground lead was located at AFz and the right mastoid was set as a reference.

EEG data were processed using EEGLAB (Delorme & Makeig, 2004), an open source toolbox running in the MATLAB environment. Continuous EEG data were filtered with a 30 Hz low-pass filter and a 0.1 Hz high-pass filter and were re-referenced to average mastoids. EEG epochs were extracted using a window time from − 1000–2000 ms that was time-locked to the stimulus onset, and were baseline corrected using the pre-stimulus interval. In line with conventional practices some data were modified or removed a priori. First, data from incorrect trials were removed. Second, data from trials with large drift were manually removed. Third, data from trials contaminated by eyeblinks were modified using an independent component analysis (ICA) algorithm (infomax) (Delorme & Makeig, 2004). Fourth and last, data from trials with amplitude values exceeding ± 75 μV at any electrode were removed. After data removal, in the Flanker task, (1) in the pre-training session, the mean number of incongruent trials was 227.98 (SD = 32.83), and the mean number of congruent trials was 237.79 (SD = 30.80); (2) in the post-training session, the mean number of incongruent trials was 222.40 (SD = 36.57), and the mean number of congruent trials was 228.13 (SD = 36.97). After data removal, in the Go/Nogo task, (1) in the pre-training session, the mean number of Go trials was 220.79 (SD = 18.04), and the mean number of Nogo trials was 68 (SD = 7.81); (2) in the post-training session, the mean number of Go trials was 207.11 (SD = 28.41), and the mean number of Nogo trials was 63.25 (SD = 10.31).

The EEG data used for ERP analysis were baseline corrected using the pre-stimulus interval (−200 to 0 ms). Consistent with previous research (Folstein & Van Petten, 2007; Kopp, Rist, & Mattler, 1996; Pratt et al., 2011) and based on visual inspection of ERP waveforms and topographical maps: (1) in the Flanker task, the N2 amplitude was quantified as the negative mean amplitude at Cz between 220 and 360 ms post-stimulus onset; the P3 amplitude was quantified as the positive mean amplitude at CPz between 300 and 600 ms post-stimulus onset; and (2) in the Go/Nogo task, the N2 amplitude was quantified as the negative mean amplitude at Cz between 220 and 360 ms post-stimulus onset; the P3 amplitude was quantified as the positive mean amplitude at CPz between 300 and 600 ms post-stimulus onset.

An estimate of the oscillatory power as a function of time and frequency (time–frequency representation) was obtained from single-trial EEG epochs using complex Morlet wavelet analysis conducted by the Fieldtrip toolbox (Oostenveld, Fries, Maris & Schoffelen, 2011). The following parameters were relied on: the width was set to 4.5, the frequency range spanned 2–30 Hz in steps of 1 Hz and the time interval was set between -1000–2000 ms in steps of 10 ms. Single trial time–frequency representations were then averaged to obtain averaged time–frequency representations which were used to identify the modulations of ongoing EEG rhythms (ERSP). For each estimated frequency, ERSP magnitudes were displayed as the increase or decrease in oscillatory power relative to the pre-stimulus interval (−400 to −200 ms) according to the following formula: $ER_{t,f}\% = [A_{t,f} - R_f]/R_f$, where $A_{t,f}$ was the signal power at a given time (t) and frequency (f), and R_f was the signal power averaged within the pre-stimulus interval (Pfurtscheller & Da Silva, 1999). Then, consistent with previous research (Cavanagh & Frank, 2014; Nigbur, Ivanova, & Stürmer, 2011; Scharinger, Soutschek, Schubert & Gerjets, 2015; Tang, Hu, & Chen, 2013), and based on visual inspection of group-averaged time-frequency spectrograms: (1) in the Flanker task, we calculated the mean magnitude of theta activities across the frequencies 4–7 Hz in the time window of 100–600 ms post-stimulus onset at FCz, and calculated the mean magnitude of alpha activities across the frequencies 8–13 Hz in the time window of 300–600 ms post-stimulus onset at Pz; and (2) in the Go/Nogo task, we calculated the mean magnitude of theta activities across the frequencies 4–7 Hz in the time window of 100–600 ms post-stimulus onset at FCz, and calculated the mean magnitude of alpha activities across the frequencies 8–13 Hz in the time window of 0–400 ms post- stimulus onset at Pz.

2.6. *Statistical analysis*

The statistical analyses were carried out using IBM SPSS Statistics 23.0. Based on previous studies (Lotfi et al., 2021; Swainston & Derakshan, 2018), multilevel modelling (MLM, also known as Linear Mixed Effect Model) was used to compare groups (training and control) on TAS score or attentional control related measures over time. In the MLM model, fixed effects were estimated for “time” (pre-training and post-training), “group” (training and control) and one interaction effect: “time*group”. Maximum likelihood estimation was relied on. Relevant MLM simple effect analyses (i.e., multiple comparisons) were conducted after a significant interaction effect was identified. Multiple comparisons were adjusted using a Bonferroni correction. Effect sizes were assessed by means of Cohen’s d which was derived from the F-test statistic using the following formula: $d = 2 * \sqrt{(F / df)}$. In the Results section data are typically presented as Mean ± Standard Error: M ± SE.

3. Results

3.1. *Working memory training*

Task performance improvement in the working memory training group related to the three working memory training tasks (letter/ animal/ location) are shown in Fig. 3. Working memory performance in the training session, as indicated by item presentation time decreased significantly from the first day to the last day: letter: $t(20) = 84.57$, $p < 0.001$, Cohen’s $d = 18.45$, (last day: 211.13 ± 13.68 ms; first day: 1506.35 ± 6.35 ms) ; animal: $t(20) = 13.87$, $p < 0.001$, Cohen’s $d = 3.03$, (last day: 385.71 ± 21.65 ms; first day: 1225.40 ± 64.73 ms); location: $t(20) = 32.06$, $p < 0.001$, Cohen’s $d = 7.00$, (last day: 160.30 ± 13.91 ms; first day: 1542.86 ± 45.08 ms) .

3.2. *TAS*

The results of TAS are shown in Table 1. Using the TAS score as the dependent variable, the MLM analyses showed no significant main effect for time, $F(1, 47) = 1.69$, $p = 0.20$, Cohen’s $d = 0.38$; and group, $F(1, 47) = 0.13$, $p = 0.72$, Cohen’s $d = 0.11$. The interaction effect between time and group was also not statistically significant, $F(1, 47) = 0.20$, $p = 0.65$, Cohen’s $d = 0.13$.

We examined the correlations between the WMT training improvement (item presentation time at the last training day - item presentation time at training day 1) and the change in self-reported test anxiety (post-training - pre-training). The results showed no significant correlations between the change in self-reported test anxiety and WMT training improvement (letter: $r(19) = -0.16$, $p = 0.48$; animal: $r(19) = 0.07$, $p = 0.75$; location: $r(19) = 0.04$, $p = 0.86$).

Table 1
Pre- and post-training TAS scores and behavioral results (M ± SE) for all conditions.

Scale/ Task	Outcome variable	Training group		Control group	
		Pre	Post	Pre	Post
TAS	Sum score	24.14 ± 0.98	23.19 ± 1.17	23.42 ± 0.88	22.96 ± 1.06
Flanker	RTs incongruent	450.56 ± 12.49	452.02 ± 11.56	453.48 ± 11.23	461.41 ± 10.39
	RTs congruent	399.59 ± 11.19	398.46 ± 9.80	394.38 ± 10.05	403.05 ± 8.81
	ACC incongruent	94.75% ± 0.92%	95.69% ± 1.06%	96.69% ± 0.83%	96.12% ± 0.95%
	ACC congruent	99.62% ± 0.10%	99.39% ± 0.75%	99.75% ± 0.09%	98.28% ± 0.67%
Go/ Nogo	RTs Go	399.41 ± 9.33	407.53 ± 10.65	392.94 ± 8.38	404.76 ± 9.57
	ACC Go	99.42% ± 0.23%	99.15% ± 0.27%	99.73% ± 0.21%	99.73% ± 0.24%
	ACC Nogo	90.65% ± 1.19%	91.19% ± 1.28%	93.12% ± 1.07%	91.15% ± 1.15%

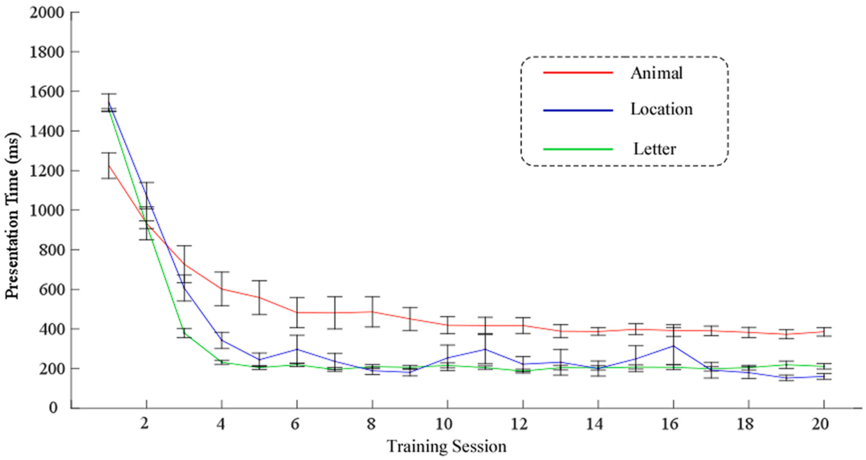

Fig. 3. Item presentation time of the three working memory training tasks throughout the 20 training days. Error bars represent standard errors.

3.3. Flanker task

3.3.1. Behavioral results

The results on reaction times (RTs) and accuracy for the Flanker task are shown in Table 1. Using the RTs as the dependent variable, for both incongruent and congruent trials, the MLM analyses showed no significant main effect for time, group, and their interaction effect was also not statistically significant. Using the accuracy as the dependent variable, for both incongruent and congruent trials, the MLM analyses showed no significant main effect for time, group, and their interaction effect was also not statistically significant.

3.3.2. ERP data

3.3.2.1. N2 amplitude. The results on ERP waveforms for the Flanker task are shown in Fig. 4. Using N2 amplitude as the dependent variable, for incongruent trails, the MLM analyses showed a significant main effect for time, $F(1,\ 47) = 43.69$, $p < 0.001$, Cohen's $d = 1.93$, which attested to a larger N2 amplitude in the post-training session (-2.82 ± 0.63 μV) when compared to the pre-training session (-0.18 ± 0.68 μV). There is no significant main effect for group, and the interaction effect was also not statistically significant. For congruent trails, the MLM analyses showed a significant main effect for time, $F(1,\ 47) = 33.77$, $p < 0.001$, Cohen's $d = 1.7$, which attested to a larger N2 amplitude in the post-training session (-1.02 ± 0.62 μV) when compared to the pre-training session (1.60 ± 0.71 μV). There is no significant main effect for group, and the interaction effect was also not statistically significant.

3.3.2.2. P3 amplitude. The results on ERP waveforms for the Flanker task are shown in Fig. 5. Using P3 amplitude as the dependent variable, for incongruent trails, the MLM analyses showed a significant main effect for time, $F(1,\ 47) = 15.07$, $p < 0.001$, Cohen's $d = 1.13$, which attested to a smaller P3 amplitude in the post-training session (4.24 ± 0.61 μV) when compared to the pre-training session (6.44 ± 0.68 μV). There is no significant main effect for group, and the interaction effect was also not statistically significant. For congruent trails, the MLM analyses showed a significant main effect for time, $F(1,\ 47) = 20.33$, $p < 0.001$, Cohen's $d = 1.32$, which attested to a smaller P3 amplitude in the post-training session (4.32 ± 0.58 μV) when compared to the pre-training session ($6.98 \pm 0.\ 67$ μV). There is no significant main effect for group, and the interaction effect was also not statistically significant.

3.3.3. ERSP data

3.3.3.1. Theta power. The results on ERSP for the Flanker task shown in Fig. 6. Using the theta power as the dependent variable, for incongruent trails, the MLM analyses showed a significant main effect for time, $F(1,\ 47) = 7.83$, $p = 0.007$, Cohen's $d = 0.82$, which attested to a smaller theta power in the post-training session (0.72 ± 0.08) when compared to the pre-training session (0.87 ± 0.08). No significant main effect was reported for group, and the interaction effect was also not statistically significant. For congruent trails, the MLM analyses showed a significant main effect for time, $F(1,\ 47) = 6.92$, $p = 0.01$, Cohen's $d = 0.77$, which attested to a smaller theta power in the post-training session (0.37 ± 0.05) when compared to the pre-training session (0.45 ± 0.06). No significant main effect was reported for group, and the interaction effect was also not statistically significant.

3.3.3.2. Alpha power. The results of ERSP for the Flanker task are shown in Fig. 7. Using the alpha power as the dependent variable, for both incongruent and congruent trails, the MLM analyses showed no significant main effect for time, group, as well as their interaction effect.

3.3.4. Correlations between the changes in behavioral and neurophysiological results

3.3.4.1. RTs. We examined the correlations between the RTs change (post-training - pre-training) and the neurophysiological changes (post-training - pre-training). The results showed that, (1) in the training

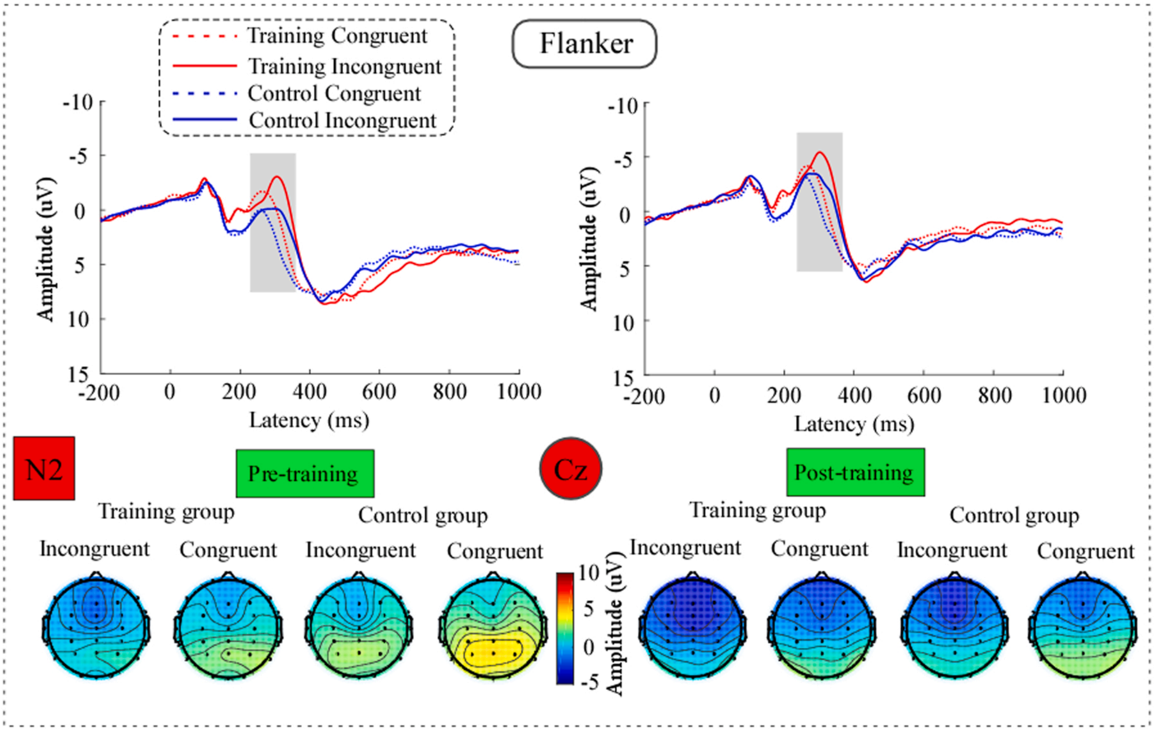

Fig. 4. Flanker related grand means of the ERP waveforms for all conditions at electrode site Cz (upper part). Additionally, the topographies of the N2 amplitude are given (lower part).

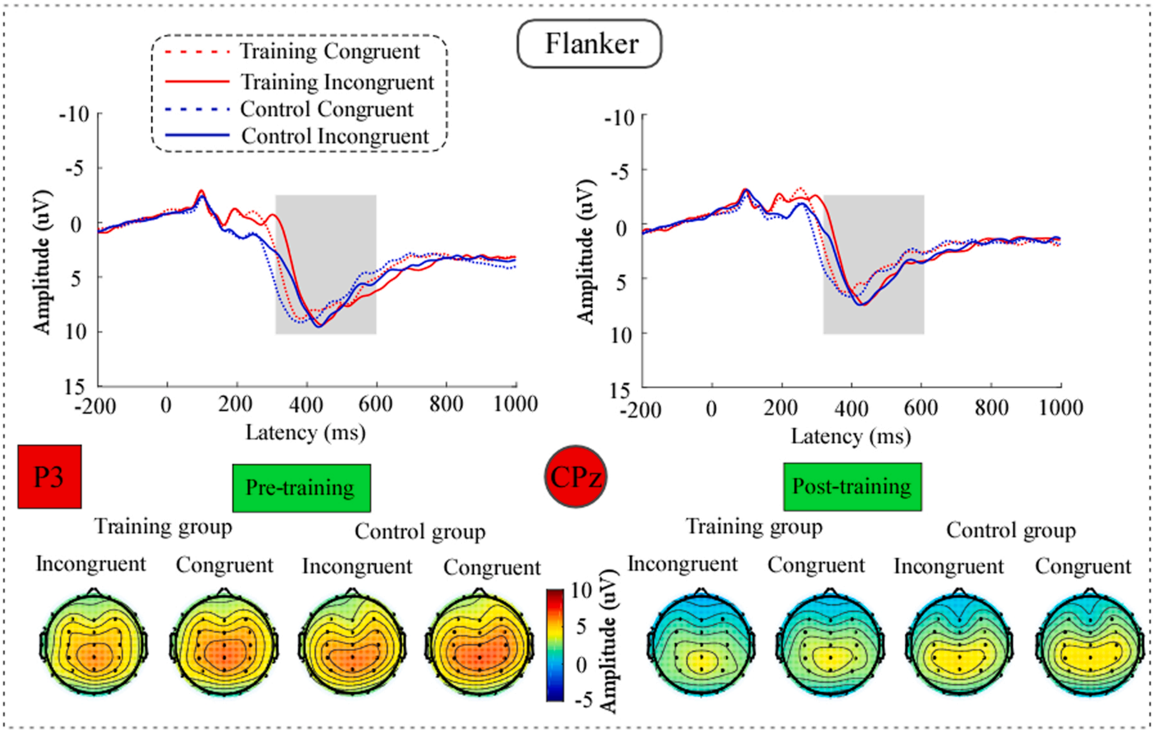

Fig. 5. Flanker related grand means of the ERP waveforms for all conditions at electrode site CPz (upper part). Additionally, the topographies of the P3 amplitude are given (lower part).

group, there were significant correlations between the change in RTs and the N2 amplitude change, ($r(19) = -0.43, p = 0.05$, Fig. S1), as well as the P3 amplitude change, ($r(19) = -0.49$, $p = 0.02$, Fig. S2) for incongruent trials; no significant change-related correlation was found for congruent trials; (2) in the control group, no significant change-related correlation was found for both incongruent and congruent trials.

3.3.4.2. Accuracy. We examined the correlations between the accuracy change (post-training - pre-training) and the neurophysiological changes (post-training - pre-training). The results showed that, (1) in the training group, there were significant correlations between the accuracy change and the P3 amplitude change for incongruent trials, ($r(19) = -0.57$, $p = 0.007$, Fig. S3), and congruent trials, ($r(19) = -0.45$, $p = 0.04$, Fig. S4); (2) in the control group, no significant change-related correlation was found for incongruent trials; for congruent trials, however, there was a significant correlation between the accuracy change and the P3 amplitude change, ($r(24) = -0.42, p = 0.03$, Fig. S5).

3.4. Go/Nogo task

3.4.1. Behavioral results

The results on RTs and accuracy for Go/Nogo task are shown in Table 1. Using Go RTs and Go accuracy as the dependent variable separately, MLM analyses showed no significant main effect for time, group, and no significant interaction effect. Using Nogo accuracy as the dependent variable, MLM analyses showed no significant main effect for time and group. There was a trend towards a significant interaction, $F(1, 47) = 3.83$, $p = 0.056$, Cohen's $d = 0.57$. Follow-up analyses showed that participants in the control group reach lower accuracy in the post-training session (91.15% ± 1.15%) when compared to the pre-training session (93.12% ± 1.07%, p = 0.03).

3.4.2. ERP data

3.4.2.1. N2 amplitude. The results on ERP waveforms for the Go/Nogo task are shown in Fig. 8. Using N2 amplitude as the dependent variable, for Go trials, the MLM analyses showed a significant main effect for time, $F(1, 47) = 50.99, p < 0.001$, Cohen's $d = 2.08$, which attested to a larger N2 amplitude in the post-training session (0.75 ± 0.58 μV) when compared to the pre-training session (3.57 ± 0.64 μV). No significant main effect was reported for group, and the interaction effect was also not statistically significant. For Nogo trials, the MLM analyses showed a significant main effect for time, $F(1, 47) = 32.59$, $p < 0.001$, Cohen's $d = 1.67$, which attested to a larger N2 amplitude in the post-training session (−0.58 ± 0.68 μV) when compared to the pre-training session (2.46 ± 0.77 μV). No significant main effect was reported for group, and the interaction effect was also not statistically significant.

3.4.2.2. P3 amplitude. The results on ERP waveforms for the Go/Nogo task are shown in Fig. 9. Using P3 amplitude as the dependent variable, for Go trails, the MLM analyses showed a significant main effect for time, $F(1, 47) = 18.23$, $p < 0.001$, Cohen's $d = 1.25$, which attested to a smaller P3 amplitude in the post-training session (5.86 ± 0.60 μV) when compared to the pre-training session (7.75 ± 0.67 μV). No significant main effect for group was reported, and the interaction effect was also not statistically significant. For Nogo trails, the MLM analyses showed a significant main effect for time, $F(1, 47) = 14.92$, $p < 0.001$, Cohen's $d = 1.13$, which attested to a smaller P3 amplitude in the post-training session (7.56 ± 0.80 μV) when compared to the pre-training session (10.48 ± 0.77 μV). No significant main effect for group was reported, and the interaction effect was also not statistically significant.

3.4.3. ERSP data

3.4.3.1. Theta power. The results on ERSP data for the Go/Nogo task shown in Fig. 10. Using theta power as the dependent variable, for Go trails, the MLM analyses showed a significant main effect for time, $F(1, 47) = 5.18, p = 0.03$, Cohen's $d = 0.66$, which attested to a smaller theta power in the post-training session (0.36 ± 0.05) when compared to the pre-training session (0.44 ± 0.0.05). No significant main effect for group

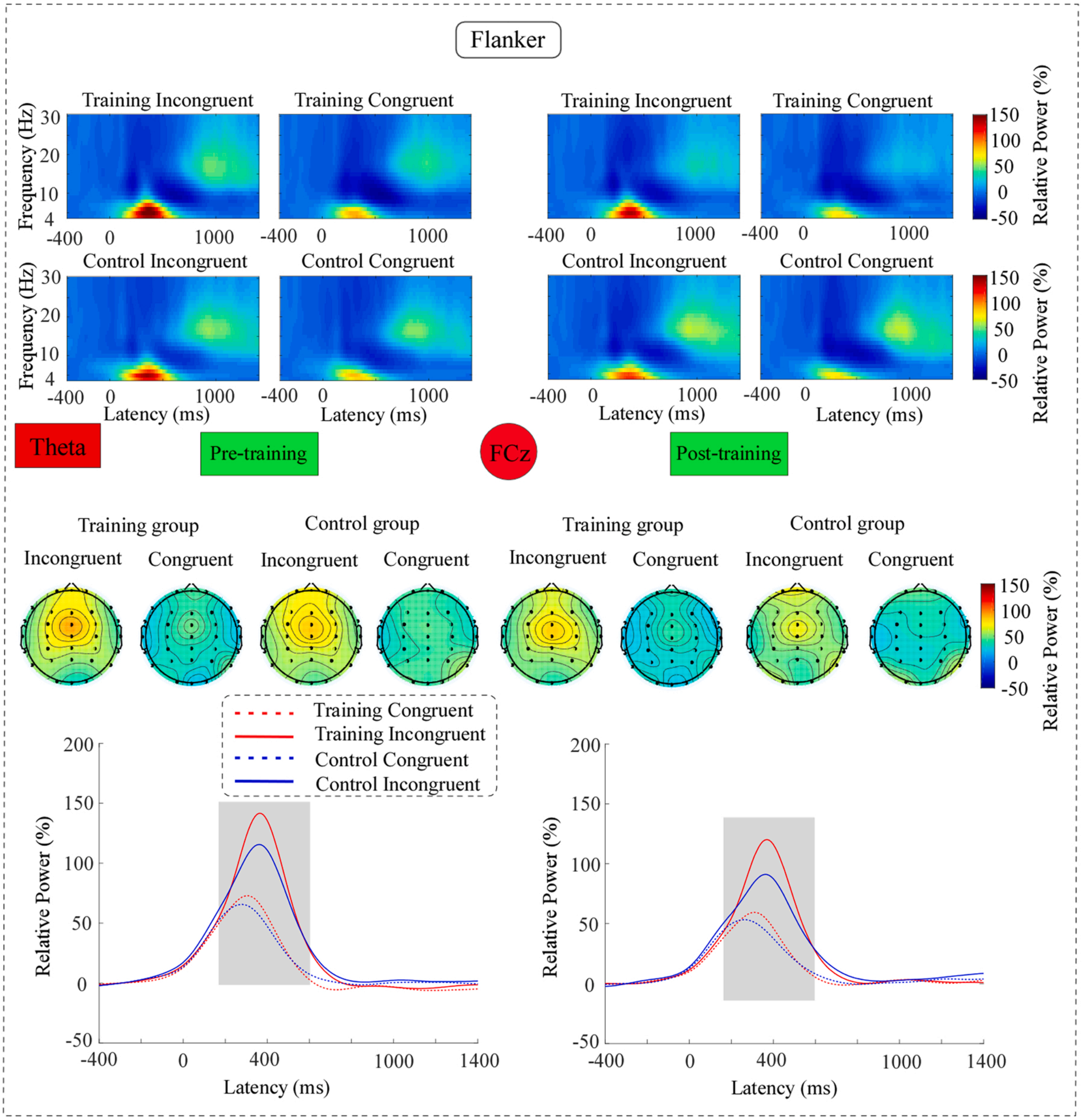

Fig. 6. Flanker related spectrograms of the mean ERSP for all conditions at electrode FCz (upper part); The topographies of theta power for each condition (middle part); The time course of theta power (lower part).

was reported, and the interaction effect was also not statistically significant. For Nogo trails, the MLM analyses revealed that the main effect for time showed a trend towards a significant effect, $F(1, 47) = 3.65$, $p = 0.06$, Cohen's $d = 0.56$, which attested to a smaller theta power in the post-training session (1.24 ± 0.11) when compared to the pre-training session (1.39 ± 0.10). No significant main effect for group was reported, and the interaction effect was also not statistically significant.

3.4.3.2. Alpha power. The results on ERSP data for the Go/Nogo task shown in Fig. 11. Using alpha power as the dependent variable, for Go trails, the MLM analyses showed no significant main effect for time, group, and the interaction effect was also not found to be significant. For Nogo trails, the MLM analyses showed a significant main effect for time, $F(1, 47) = 8.49$, $p = 0.005$, Cohen's $d = 0.85$, which attested to a smaller alpha power in the post-training session (−0.08 ± 0.03) when compared to the pre-training session (0.02 ± 0.04). No significant main effect for group was reported. The interaction effect was statistically significant, $F(1, 47) = 4.55$, $p = 0.04$, Cohen's $d = 0.62$. Follow-up analyses showed that participants in the training group had a smaller alpha power in the post-training session (−0.10 ± 0.05) when compared to the pre-training session (0.06 ± 0.06, $p = 0.001$).

3.4.4. Correlations between the changes in behavioral and neurophysiological results

3.4.4.1. Go RTs. We examined the correlations between the Go RTs change (post-training - pre-training) and the neurophysiological changes (post-training - pre-training). The results showed that, (1) in the training group, no significant change-related correlation was found; (2) in the control group, a significant correlation between the Go RTs change and the Go P3 amplitude change was reported, ($r(24) = -0.49$, $p = 0.01$, Fig. S6).

3.4.4.2. Go accuracy. We examined the correlations between Go accuracy change (post-training - pre-training) and the neurophysiological changes (post-training - pre-training). Results revealed no significant change-related correlations in both the training and the control groups.

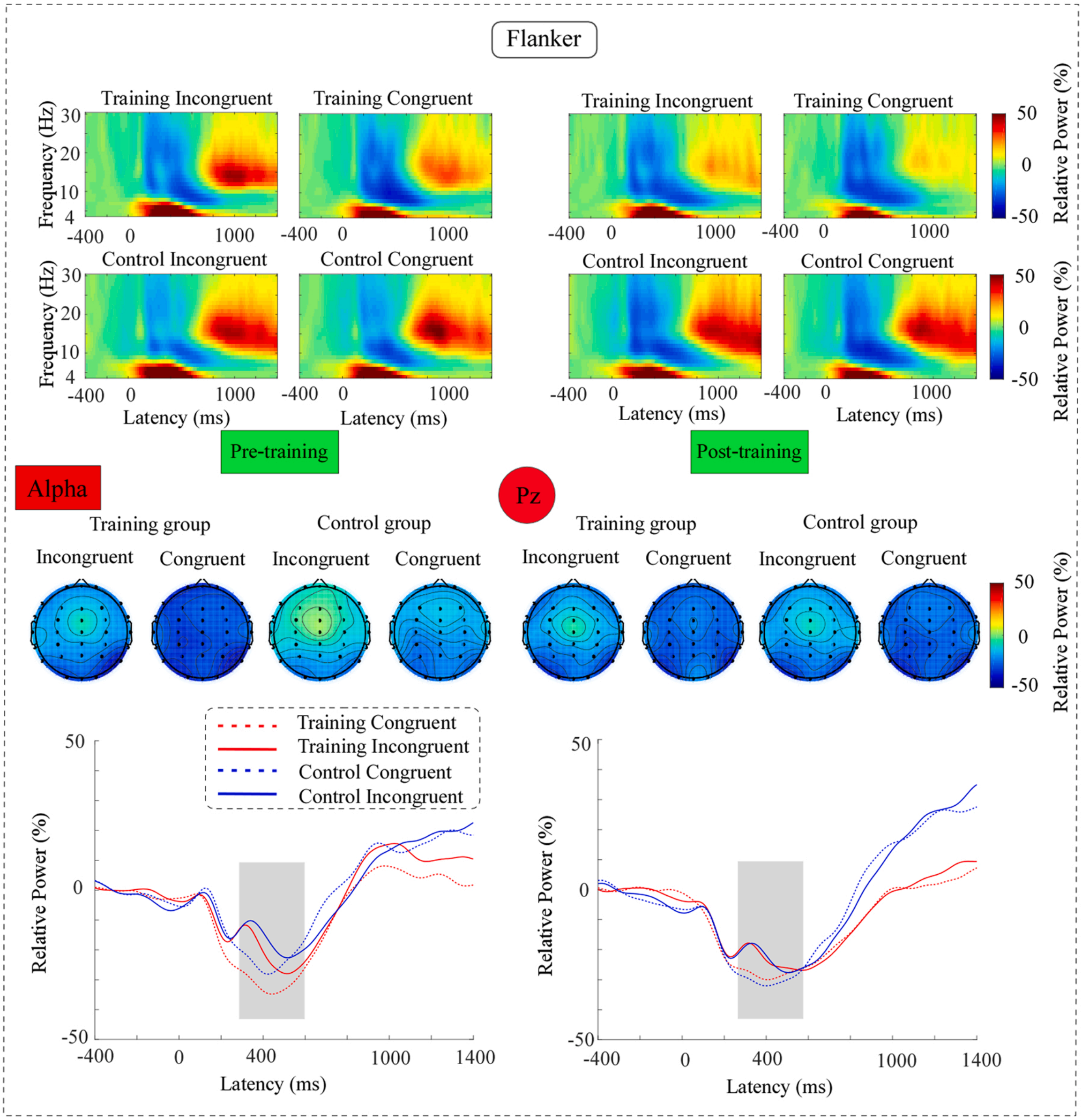

Fig. 7. Flanker related spectrograms of the mean ERSP for all conditions at electrode Pz (upper part); The topographies of alpha power for each condition (middle part); The time course of alpha power (lower part).

3.4.4.3. Nogo accuracy. We examined the correlations between the Nogo accuracy change (post-training - pre-training) and the neurophysiological changes (post-training - pre-training). The results showed that, (1) in the training group, a significant correlation between the Nogo accuracy change and the Nogo theta power change, ($r(19) = 0.44$, $p = 0.04$) was found (Fig. S7); (2) in the control group, no significant change-related correlation was found.

4. Discussion

The mixed evidence obtained so far regarding possible beneficial effects of neutral working memory training (i.e., working memory training using neutral materials) on high anxious or worried individuals' attentional control ability, with possible transfer effects on inhibition related performance, has triggered the design of our study. Our research design was such that it attempted to minimize potential confounds such as placebo effects, and provide comprehensive neurophysiological insights on potential effects of neutral working memory training (through ERP and ERSP). In particular our study examined whether neutral working memory training could improve HTA individuals' attentional control ability. The findings revealed beneficial neurophysiological transfer effects of neutral working memory training, an improvement which manifested itself as a decrease in Nogo alpha power in the training group after neutral working memory training (i.e., post-outcome versus pre-outcome) compared to the control group. In contrast to our expectations, we failed to provide evidence for beneficial transfer effects of neutral working memory training on enhanced task performance of both Flanker and Go/Nogo tasks in the training group compared to the control group. Also in contrast to our expectations, no significant reduction in the level of test anxiety in HTA individuals was found.

We will now reflect more deeply on how our experimental research results add value to the neurophysiological and behavioral insights that could already be obtained from earlier research. Previous research showed that working memory capacity is based on attentional control (Eriksson, Vogel, Lansner, Bergström & Nyberg, 2015), and that adaptive neutral working memory training could improve high anxious or worried individuals' attentional control ability (Course-Choi et al.,

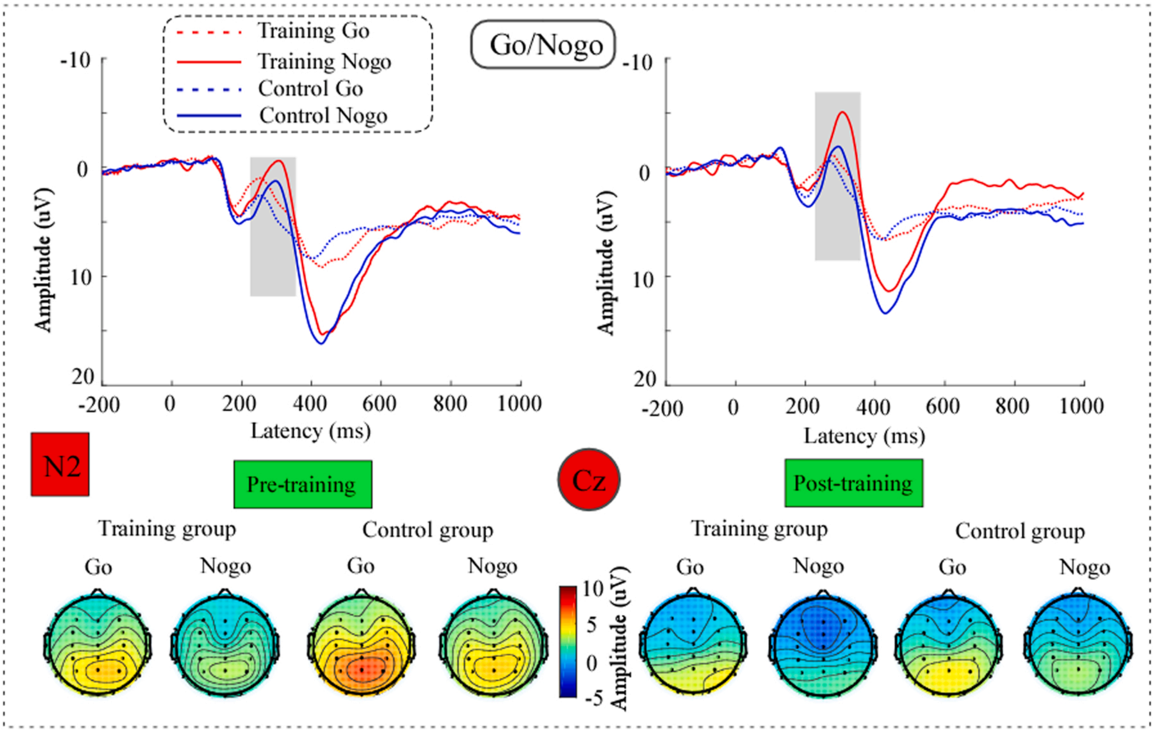

Fig. 8. Go/Nogo related grand means of the ERP waveforms for all conditions at electrode site Cz (upper part). Additionally, the topographies of the N2 are given (lower part).

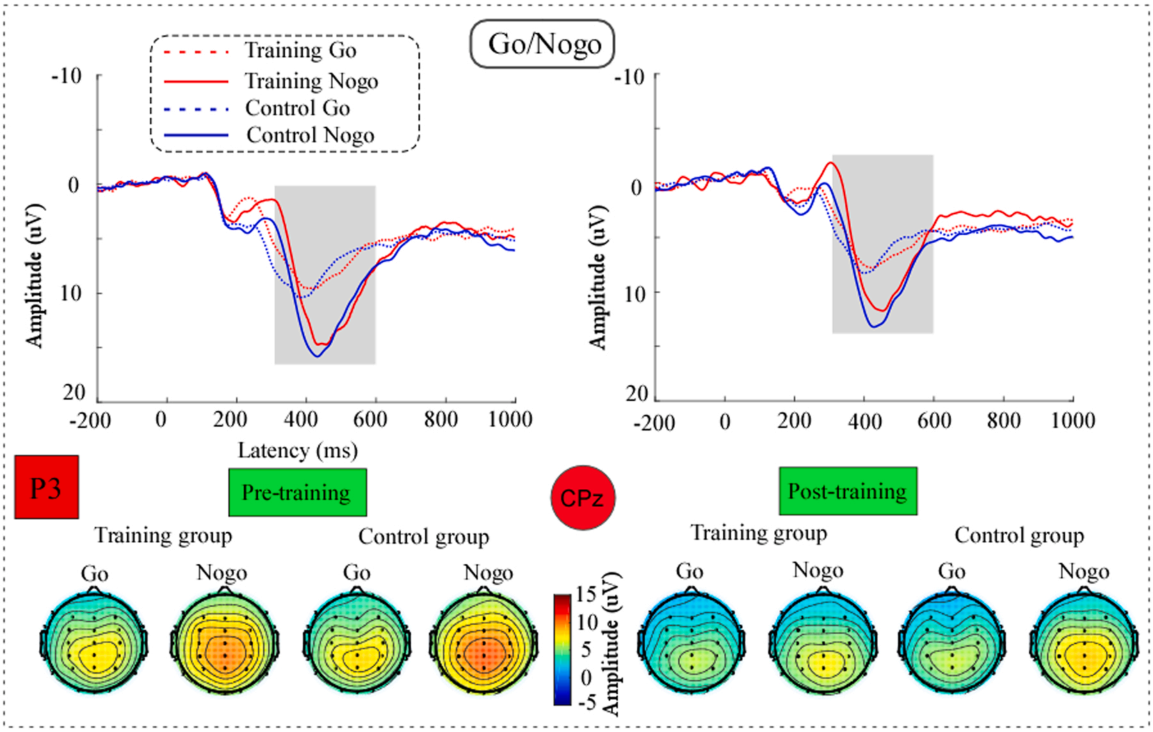

Fig. 9. Go/Nogo related grand means of the ERP waveforms for all conditions at electrode site CPz (upper part). Additionally, the topographies of the P3 are given (lower part).

2017; Hadwin & Richards, 2016; Sari et al., 2016). However, as mentioned above, previous research produced mixed experimental results on the exact beneficial transfer effects of neutral working memory training, in particular enhancement of inhibition performance (Hotton et al., 2018; Sari et al., 2016; Zhao et al., 2020). Specifically, individuals in the training group displayed a decrease in alpha power from the pre- to the post-training sessions compared to the control group. The idling hypothesis claims that a decrease in alpha power may reflect an individual's increased attention to the experimental task (Pfurtscheller et al., 1996). Thus, our study showed that, after neutral working

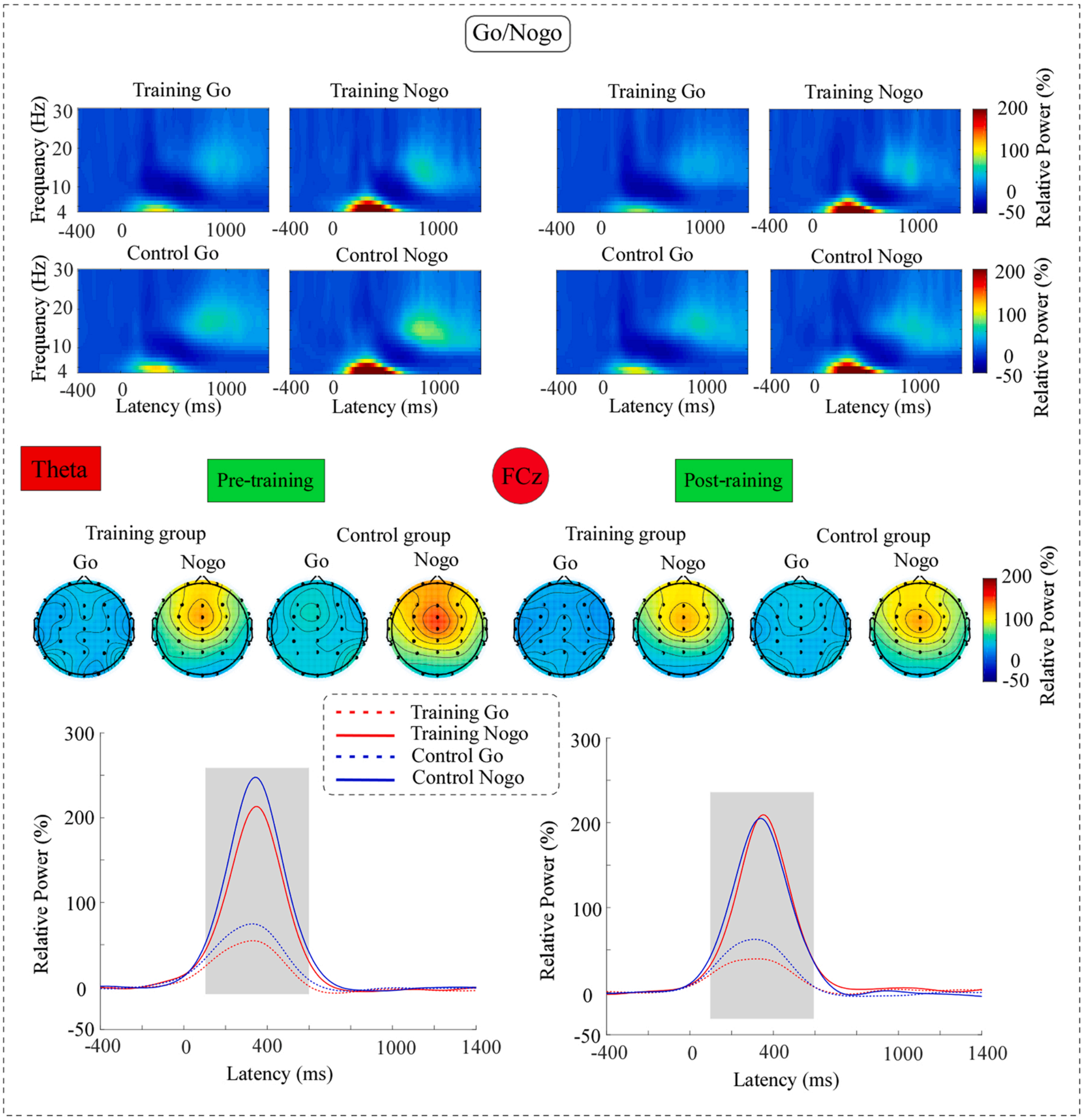

Fig. 10. Go/Nogo related spectrograms of the mean ERSP for all conditions at electrode FCz (upper part); The topographies of theta power for each condition (middle part); The time course of theta power (lower part).

memory training, individuals in the training group could enhance attentional resources to complete the experimental task. However, our study showed that the beneficial transfer effects from neutral working memory training in the training group did neither include a significant decrease of the Nogo P3 amplitude nor a significant increase of both the N2 amplitude and theta power, as compared to the control group (X. Wang & Covey, 2020). The Nogo P3 amplitude may reflect the monitoring of the outcome of inhibition or motor inhibition, which is not related directly to attentional control resource allocation (Sehlmeyer et al., 2010; Smith et al., 2008; Zordan et al., 2008). Previous studies have shown that: (1) both N2 amplitude and the theta oscillation constitute the underlying neurophysiological mechanism for conflict detection, monitoring, and conflict resolution processes, and (2) the combination of an increased N2 amplitude and an increased theta power are related to increased recruitment of attentional control (Cavanagh & Frank, 2014; Gonzalezvillar & Carrillodelapena, 2017; Nigbur et al., 2011). Above all, the findings of our present study only revealed partial neurophysiological evidence of neutral working memory training with possible transfer effects while performing the Go/Nogo task.

Not in line with our study expectations, our experimental results failed to show beneficial transfer effects in the training group on Flanker task performance compared to the control group. Interestingly, past experimental research (i.e., the study by Sari et al. (2016)) could only demonstrate beneficial transfer effects from neutral working memory training in Flanker task performance in a noise stress condition. In two experimental studies, the one by Sari et al. (2016) and another one by Hotton et al. (2018), beneficial transfer effects of neutral working memory training on Flanker task performance were not observed in a no noise stress condition. In our present study, the implementation of a test-related stress situation is different from a noise stress situation, especially in terms of the experimental situation's extent to which available attentional control resources (for HTA individuals) can be reduced. So, our study further provided evidence that neutral working memory training had no beneficial transfer effects on Flanker task performance in HTA individuals.

Inhibition is known to be composed of two component processes: interference suppression and response inhibition (Friedman & Miyake, 2004). Both interference suppression and response inhibition related

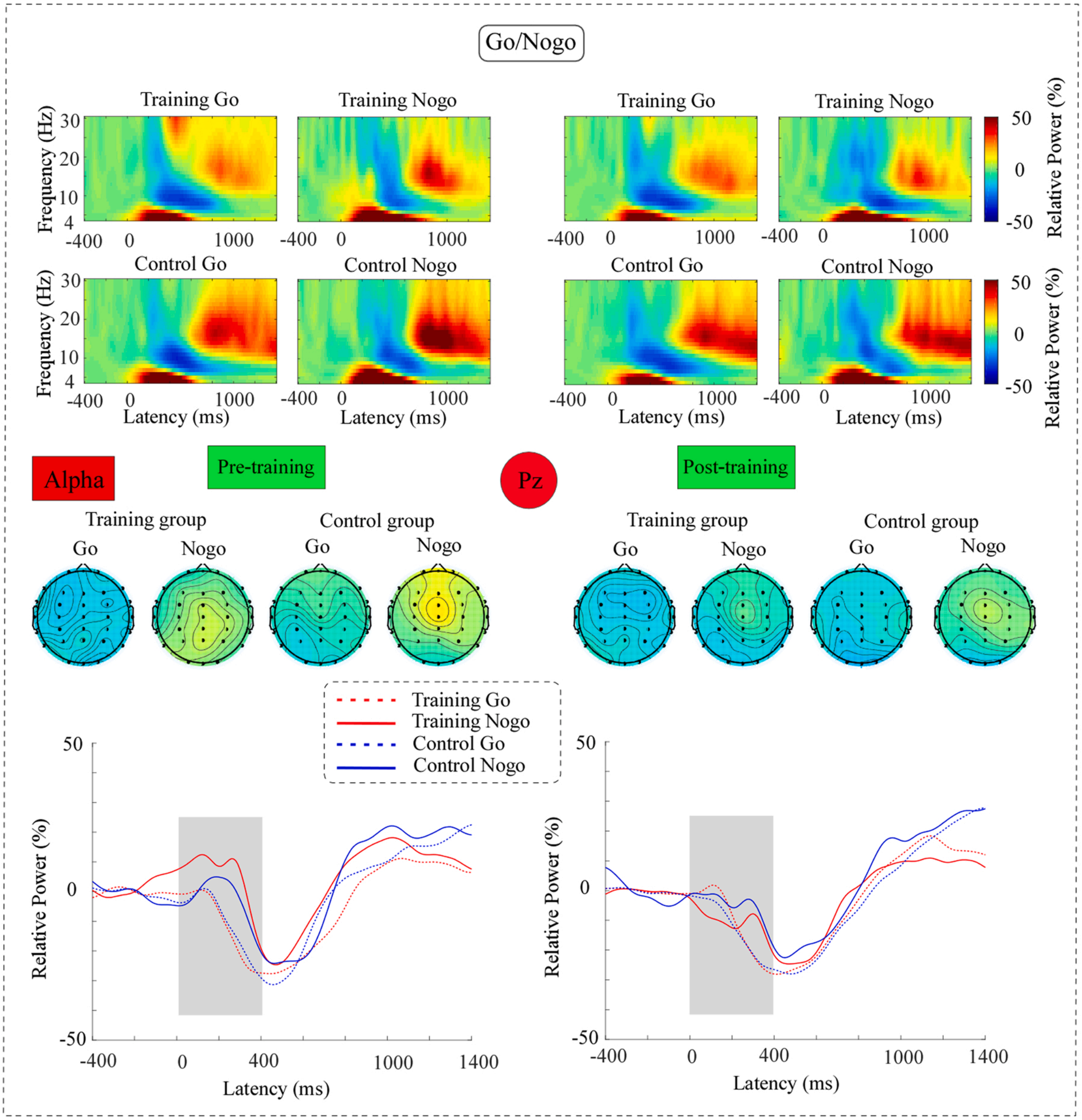

Fig. 11. Go/Nogo related spectrograms of the mean ERSP for all conditions at electrode Pz (upper part); The topographies of alpha power for each condition (middle part); The time course of alpha power (lower part).

experimental tasks can be used to examine individuals' attentional control ability. However, there is "experimental task variability" in that different experimental tasks may require different attentional control resources demands (Brydges et al., 2012). Both interference suppression and response inhibition consume attentional control resources, supplementary to the experimental task (Friedman & Miyake, 2004). Successful completing a Flanker task requires more attentional control resources than successful completing a Go/Nogo task (Brydges et al., 2012). This between-task difference may be responsible for the observed between-task significance difference in beneficial transfer effects on attentional control resources (due to neutral working memory training), that is a significant result for the Go/Nogo task and no significant result for the Flanker task.

Previous experimental studies showed that neutral working memory training could reduce anxiety symptoms in high anxious individuals (Beloe & Derakshan, 2019; Hotton et al., 2018; Zhao et al., 2020). It is known that an attentional control deficit, which is typical for HTA individuals, may form a risk for further developing anxiety symptoms (Zainal & Newman, 2018). However, in our present study, neutral working memory training gains were not associated with a reduction in the TAS scores after a 20 days' working memory training. We now give two possible explanations. Firstly, as recently demonstrated, some existing studies provide complementary insights in that they fail to report a reduction in self-reported anxiety symptoms as a result of neutral working memory training (Sari et al., 2016; Wanmaker, Geraerts, & Franken, 2015). This finding clearly contrasts emotional working memory training studies pointing in the direction of significant improvement of attentional control and a significant reduction of anxiety symptoms in high anxious individuals (Lotfi et al., 2021; Minihan et al., 2021). The differential findings obtained with neutral versus emotional working memory training goes beyond the scope of our present study. Future studies could try to also unravel different mechanisms underlying neutral and emotional working memory training. Secondly, in the present study, transfer effects of neutral working memory training were either limited in size, with only neurophysiological change while performing the Go/Nogo task, but not Flanker task. Possibly, neurophysiological training sessions with a longer duration than relied on in our study may, at least potentially, still contribute to improved attentional control ability in HTA individuals, including a significant beneficial transfer effect, namely the reduction of self-reported anxiety symptoms.

Our behavioral results showed that HTA individuals in the control group showed a reduction of Nogo accuracy after neutral working memory training. The active control group should, at least in theory, be effective in minimizing potential confounds such as placebo effects. In practice, however, too low difficulty level of the (90 times repeated) easy working memory training task as performed by HTA individuals in the control group may have led to a reduced level of enthusiasm while conducting the experimental task. This reduced level of enthusiasm may, in turn, have led to a reduction in experimental task accuracy over the course of the experiment. Follow-up studies may, therefore, reconsider important design aspects of the working memory training task offered to the control group.

Some limitations of the present study may explain why no beneficial transfer effects (in particular enhanced task performance) of neutral working memory training were found in both Flanker and Go/Nogo tasks. First, since a significant "time effect" was reported, the findings revealed partial beneficial neurophysiological transfer effects (i.e. Nogo alpha power) of neutral working memory training for HTA individuals in the training group, as compared to the control group. Thus, the partial beneficial neurophysiological transfer effects we did observe could either be exclusively due to the training itself or, alternatively, be due to other factors. A final statement cannot be made yet. Additional research with well-designed control groups is needed to determine what combinations of "other factors" may, at least partially, account for the beneficial results obtained. Second, although participants were required to complete the working memory training task 20 times, it appears that most gain in improved task performance occurred within the first 6 sessions. From session 7 onwards (up to session 20) changes in the level of task engagement, participant motivation, and/or task improvement were not really different from changes observed in the control group. Future experimental studies which make use of a more effective working memory training task would help providing valuable additional insights. Third, our experimental task design relied on experimental tasks which eventually turned out to have a low "difficulty level", as indicated by an average accuracy rate in the training group exceeding 90%. The low difficulty level of the experimental task could have restricted task performance improvement of a participant during the course of the study. Future studies would benefit from relying on more difficult experimental tasks in order to provide more room for improved task performance, and to better document participants' increased attentional control ability. A fourth limitation of our study pertains to potential baseline differences between training and control groups. Although no statistically significant difference between two groups at baseline was found, the figures seemed to point towards some indicative differences. For example, Fig. 4 seems to suggest that the N2 amplitude is more pronounced in the training group compared to the control group even at baseline. As a consequence, experiment-wise, there may have been less potential for enhancement of the N2 component during the course of our experiment. Whether this fourth limitation may explain the occurrence of non-significant transfer effects, in particular: enhanced task performance due to neutral working memory training, remains – at present – an open question which may be answered in future experimental studies.

In summary, our present study provided further evidence of neutral working memory training's neurophysiological beneficial effects on the attentional control ability of HTA individuals. These beneficial effects were found to be clearly associated with important neurophysiological correlates while performing the Go/Nogo task.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.biopsycho.2022.108407.

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