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High-frequency transcranial random noise stimulation enhances unfamiliar face matching of high resolution and pixelated faces

Alejandro J. Estudillo[a,b,*], Ye Ji Lee[b], Juan A. Álvarez-Montesinos[c], Javier García-Orza[c]

[a] *Bournemouth University, UK*
[b] *University of Nottingham Malaysia, Malaysia*
[c] *Universidad de Málaga, Spain*

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ABSTRACT

Face identification is useful for social interactions and its impairment can lead to severe social and mental problems. This ability is also remarkably important in applied settings, including eyewitness identification and ID verification. Several studies have demonstrated the potential of Transcranial Random Noise Stimulation (tRNS) to enhance different cognitive skills. However, research has produced inconclusive results about the effectiveness of tRNS to improve face identification. The present study aims to further explore the effect of tRNS on face identification using an unfamiliar face matching task. Observers firstly received either high-frequency bilateral tRNS or sham stimulation for 20 min. The stimulation targeted occipitotemporal areas, which have been previously involved in face processing. In a subsequent stage, observers were asked to perform an unfamiliar face matching task consisting of unaltered and pixelated face pictures. Compared to the sham stimulation group, the high-frequency tRNS group showed better unfamiliar face matching performance with both unaltered and pixelated faces. Our results show that a single high-frequency tRNS session might suffice to improve face identification abilities. These results have important consequences for the treatment of face recognition disorders, and potential applications in those scenarios whereby the identification of faces is primordial.

1. Introduction

In a single glance to a face most people are able to determine the gender, the emotional status, whether the face is known or unknown, and, if the face is familiar, the identity of the face bearer (Bruce, 1982; Bruce & Young, 1986; Estudillo, 2012). Thus, face identification is a remarkably useful skill for daily social interactions. Most people tend to excel at familiar face recognition even after drastic changes in view, lighting, and image (for review see Johnston & Edmonds, 2009). However, some people present remarkable problems to identify even highly familiar faces. These problems can arise as a consequence of acquired brain damaged, such as in acquired prosopagnosia (Rossion, 2018), or abnormal brain development, as in developmental prosopagnosia (Barton & Corrow, 2016) or Autism Spectrum Disorder (Yucel et al., 2015). Regardless of its aetiology, people suffering face recognition impairments are more likely to suffer mental and social disorders, including depression and social anxiety (Yardley et al., 2008).

In contrast to familiar face recognition, unfamiliar face identification tends to be difficult for most people even under highly controlled laboratory conditions (Bruce et al., 1999; Burton et al., 1999; Fysh & Bindemann, 2018; Young & Burton, 2018). A classical study using a memory recognition paradigm showed that even small changes in images between encoding and recognition stages drastically reduced unfamiliar face identification (Bruce, 1982). Interestingly, this drop in accuracy is also observed even after the repeated exposure to an unfamiliar face (Longmore et al., 2008). A different task to measure unfamiliar face identification is the face matching task. In this task, which is considered the laboratory version of ID-verification at identity checkpoints (Bindemann, 2021), observers are presented with a couple of side-by-side face pictures and are asked whether the faces depict the same or two different identities (Alenezi & Bindemann, 2013; Burton et al., 2010; Estudillo et al., 2021; Estudillo & Bindemann, 2014; Johnston & Bindemann, 2013). Although this task is seemingly easy, face matching error rates of more than 20 % are commonly reported with optimized stimuli (e.g., pictures taken minutes apart, under highly controlled condition) (Burton et al., 2010; Estudillo et al., 2021; Estudillo & Wong, 2022). When the stimuli are more ecologically valid (e.g., pictures taken several months apart, under non-controlled conditions)

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* Corresponding author at: Department of Psychology, Bournemouth University, Poole House Talbot Campus, BH12 5BB UK.
E-mail address: aestudillo@bournemouth.ac.uk (A.J. Estudillo).

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the error rates are close to 40 % (Fysh & Bindemann, 2018). The high difficulty of the simultaneous face matching task is further illustrated by the fact that professionals with years of experience in ID-verification perform no better than naïve observers (Papesh, 2018; White et al., 2014).

Although it is generally assumed that faces are recognized at a global or holistic level (Estudillo et al., 2022; Rossion, 2013; Wong et al., 2021), it has been argued that the simultaneous presentation of two unfamiliar faces would encourage observers to adopt a more featural processing strategy (Megreya & Burton, 2006; Towler et al., 2017; White et al., 2015). This featural account of face matching is supported by the fact that face matching performance is positively correlated with measures of featural processing, such as object matching (Burton et al., 2010; Megreya & Burton, 2006) and inverted face matching (Megreya & Burton, 2006). In addition, professional id-verification training protocols make strong emphasis on this featural processing approach (Towler, Kemp & White, 2021). Importantly, this does not mean that holistic processing is not important for face matching (for evidence of holistic processing involvement in face matching see for example Bindemann et al., 2016; Estudillo et al., 2021; Ozbek & Bindemann, 2011). In fact, dual routes models propose that face identification can be achieved using any of these routes (Towler et al., 2021).

Given the relevance of face identification in social and applied scenarios, one question that arises is whether it is possible to improve this skill. Face identification is supported by a complex and distributed neural network involving mainly occipito-temporal brain structures, including the Occipital Face Area (OFA), the Fusiform Face Area and the posterior Superior Temporal Sulcus, and more anterior areas in the inferior frontal cortex (Duchaine & Yovel, 2015; Haxby et al., 2000). Transcranial Magnetic Stimulation (TMS) has been used to temporally disrupt specific brain areas of this network (Pitcher et al., 2011; Renzi et al., 2013). For example, research has shown that TMS over the OFA disrupts the identification of faces, but not houses, highlighting the causal role of this area in face identification (Pitcher et al., 2007, 2009).

Although TMS has been used to disrupt face identification, other stimulation techniques can be potentially used to improve this ability. One of these techniques is transcranial electrical stimulation (tES). In this technique, two or more electrodes placed in the scalp deliver a small electrical current (usually less than 2 mA) targeting relatively specific cortical brain structures (Yavari et al., 2018). The most widely used tES technique is transcranial direct current stimulation (tDCS). In tDCS, the current runs from the anode (positive) to the cathode (negative), inducing changes in the resting potential of the neurons (Krause & Cohen Kadosh, 2013; Reteig et al., 2017). tDCS improves performance of a wide range of cognitive processes, including visual perception (Clark et al., 2012), working memory (Martin et al., 2013) and mathematical cognition (Krause & Cohen Kadosh, 2013). tDCS has also been employed to improve the symptoms of neurological and psychiatric disorders, such as aphasias (Montenegro et al., 2017), depression (Brunoni et al., 2014), and learning disabilities (Krause & Cohen Kadosh, 2013).

Despite the positive effects of tDCS in cognitive processing, findings about the efficacy of this technique to improve face identification abilities are mixed. For example, 20 min 1.5 mA offline tDCS —with the anode and the cathode placed over occipito-temporal sites (PO8) and the left prefrontal cortex (Fp1), respectively— improved accuracy in face perception and face memory tasks in healthy adults (Barbieri et al., 2016; Gonzalez-Perez et al., 2019). However, these effects do not seem to be face-specific as similar improvements were found with daily life objects. In addition, other studies using the same protocol failed to find any effect of tDCS on face identification (Willis et al., 2019). A more recent report found that on-line anodal tDCS (1.5 mA) during 10 min over left dorsolateral prefrontal cortex (anodal: Fp3, cathodal: right eyebrow) enhanced the processing of upright and inverted faces. Interestingly, the effects disappear when a different part of the brain was stimulated (Civile et al., 2021).

Transcranial random noise stimulation (tRNS) is a different form of tES. In tRNS, the current is applied at quickly varying frequency bands (Krause & Cohen Kadosh, 2013; Pirulli et al., 2016) which, compared to tDCS, seems to induce larger effects in cortical excitability (Inukai et al., 2016; Murphy et al., 2020). In fact, some research has shown that, compared to tDCS, tRNS produces better enhancement in some cognitive processes, including working memory (Murphy et al., 2020) and perceptual learning (Pirulli et al., 2016).

However, similarly to tDCS, tRNS has also produced unclear findings regarding face identification. For example, an early between-subjects study with healthy volunteers found that 20 min of off-line high-frequency tRNS at 1 mA over occipito-temporal sites (P7/P8) produced better performance in the Cambridge Face Perception Test (CFPT) compared to both sham stimulation and motor cortex stimulation (Romanska et al., 2015). Interestingly, this improvement in performance was not observed for inverted faces, which suggests that this effect was face-specific. Surprisingly, a study using the Cambridge Face Memory Test, with 1.5 mA stimulation at the ventrolateral prefrontal cortex (F7/F8), found better performance after the stimulation (Experiment 1) in a between-subjects design, but inhibitory effects in a within-subject design with both young and old adults (Experiment 3) (see Penton et al., 2018). Finally, a more recent report with healthy adults in a between-subjects design found no effects of 1.5 mA occipito-temporal tRNS (PO7/PO8) on a perceptual two-alternative forced choice face discrimination task (Willis et al., 2019). Thus, given these inconclusive results, the role of tRNS on face identification requires further research that should take into consideration, different aspects of the task involved (e.g., matching vs recognition), sites (more anterior vs posterior), stimulation intensity (e.g., 1 vs 1.5 mA), design (within- vs between-participants) and modality (on-line vs off-line stimulation).

The present study aims to further investigate the role of tRNS over occipito-temporal sites on face identification. Following previous studies that showed positive effects of tRNS on face identification in between-participants, but not in within-participants, designs (Penton et al., 2018), our participants received either 20 min tRNS or sham stimulation. After the stimulation stage, they performed a face matching task. In this task, observers had to determine whether the two concurrently presented faces depicted the same or two different people. In each trial, faces were presented either unaltered or pixelated. This manipulation was included for three reasons. First, from a theoretical perspective, as face pixelation impairs the processing of fine-grained facial information (i.e., featural processing), (Bindemann et al., 2013; Lander et al., 2001), comparing the effect of tRNS on matching unfamiliar unaltered and pixelated faces can reveal further information not only about the cognitive processes involved in unfamiliar face matching, but also about the specific mechanisms boosted by the tRNS stimulation.

Second, from a methodological point of view, previous research suggests that the effects of tRNS might be stronger for more challenging tasks (Popescu et al., 2016; Reteig et al., 2017). Thus, as it has been previously shown that face identification is more challenging under pixelated conditions (Bachmann, 1991; Bindemann et al., 2013; Costen et al., 1994, 1996) the inclusion of pixelated faces seems to be a valid option to increase the chance of finding tRNS effects. Finally, from an applied point of view, low-resolution pixelated images are common in surveillance scenarios, for example when a face image from a CCTV camera is zoomed to increase its size (Bindemann et al., 2013; Jenkins & Kerr, 2013).

If high-frequency tRNS over occipito-temporal cortex modulates face perception, it would be expected that participants receiving active stimulation would outperform participants in the non-active (sham) stimulation group. Regarding the stimuli condition (high-resolution vs pixelated) we expect a superior performance in the high-resolution condition (e.g., Bindemann et al., 2013; Lander et al., 2001). It is uncertain, however, whether and how tRNS would affect each of these stimuli conditions. For instance, if tRNS enhances the processing of fine-grained detail (i.e., featural processing), we would expect to find better performance in the condition that makes the processing of facial features more challenging (i.e., pixelated condition). On the contrary, if tRNS enhances global processing, no interaction between stimuli condition and stimulation group would be expected.

2. Method

2.1. Participants

Fifty-four students from the University of Nottingham Malaysia participated in this study for course credits. Two participants were removed from further analysis due to response-key confusion. A priori power analysis using the software MorePower 6.0 (Campbell & Thompson, 2012) for a mixed ANOVA revealed that, with an alpha = 0.05, power = 0.90 and, an effect size $\eta^2p = 0.187$, based on recent research investigating the role of tRNS on unfamiliar face identification (see Penton et al., 2018), we would need at least 52 participants (26 per group). Observers were semi-randomly allocated to each group with the aim of having similar distribution in terms of race and gender/ethnicity in both groups. One group received high-frequency tRNS ($N = 27$, Mean age = 21.11, SD = 1.55; 18 females and 9 males; 1 Malaysian-Indians, 9 Malaysian-Malays, and 17 Malaysian-Chinese) or Sham stimulation ($N = 25$, Mean age = 21.4, SD = 1.45; 16 females and 9 males; 2 Malaysian-Indians, 7 Malaysian-Malays, and 16 Malaysian-Chinese). No differences across groups were found in terms of age ($t(50) = 0.58, p = .55$), sex ($\chi^2(1) = 0.04, p = .84$) or ethnicity ($\chi^2(2) = 0.05, p = .76$). Considering that progesterone and oestrogen levels influence cortical excitability, female observers were tested during the follicular phase of their menstruation cycle (Barbieri et al., 2016; Krause & Kadosh, 2014). All participants reported normal or corrected-to-normal vision, no history of seizures, neurological or psychiatric disorders and provided written informed consent before participation. This study was approved by the ethics committee of the University of Nottingham Malaysia.

2.2. Stimuli and materials

We selected a total of 90 face identities (half female) of Chinese-ethnic faces from the CAS-PEAL face database (Gao et al., 2008). Face images in this database are in greyscale and contain a uniform background. 30 identities were used in the match condition, so we had two different pictures of each of these identities. The remaining 60 identities were used to create the mismatch trials. Mismatch trials were created by the second author by pairing two faces of the same sex based on similarities between features, such as hairstyle, face contour and shape of the individual features. Background and clothes were cropped using Microsoft paint. For the pixelated condition, one of the faces of each pair was pixelated by replacing the pixels of the original face image to a smaller number of larger pixels. This was done by converting the face image into a new image with a horizontal resolution of 40 pixels per face according to the width. Each face measured maximally 462 pixels in width at a resolution of 96 ppi. The faces of each pair were positioned at a horizontal distance of 576 pixels from the screen centre. face. The position of the pixelated face (i.e., left vs right) and the order of the tasks (high-resolution vs pixelated) were counterbalanced. Example stimuli are shown in Fig. 1.

2.3. tRNS protocol

TRNS was delivered through a battery-driven current stimulator (Neuroelectrics©, Barcelona, Spain). The NG Pistim (Ag/AgCl, size: 25 mm^2) electrodes were positioned bilaterally to target the left and right occipitotemporal cortex at P7 and P8, respectively (positioned according to the 10–20 EEG system). The electrode sites selected for stimulation were in line with Romanska and colleagues' (2015) study and were based on previous research showing that P7 and P8 are located over the inferior and middle temporal gyrus, which are involved in face processing (Duchaine & Yovel, 2015; Grill-Spector et al., 2018; Weiner & Grill-Spector, 2013). In the active tRNS group, the actual current stimulation of randomly alternating (100–500 Hz) 1 mA was delivered through a pair of electrodes inserted into a neoprene cap for 20 min (see Fig. 2). In the Sham tRNS group, the stimulation was administered only for the first and last 10 s of the 20-min session just to evoke the sensation of being stimulated. These parameters were chosen based on previous research that found effects of tRNS on face perception (Romanska et al., 2015). Observers were blind to the stimulation condition.

2.4. Procedure

Following 20 min of active or Sham tRNS stimulation, observers

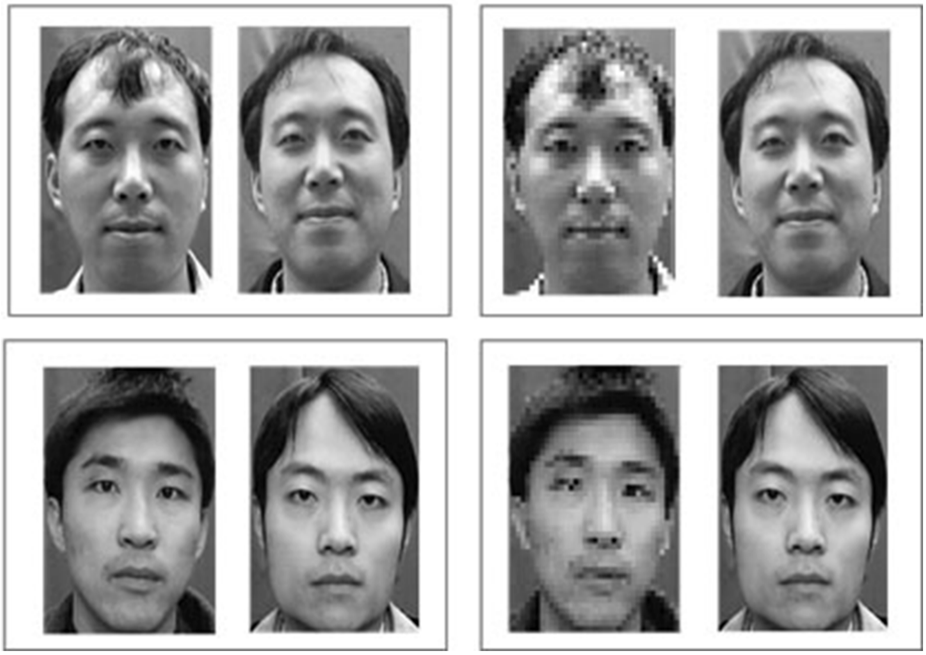

Fig. 1. Example of stimuli for the match (top row) and mismatch (bottom row) conditions in high resolution (left column) and pixelated (right column) conditions.

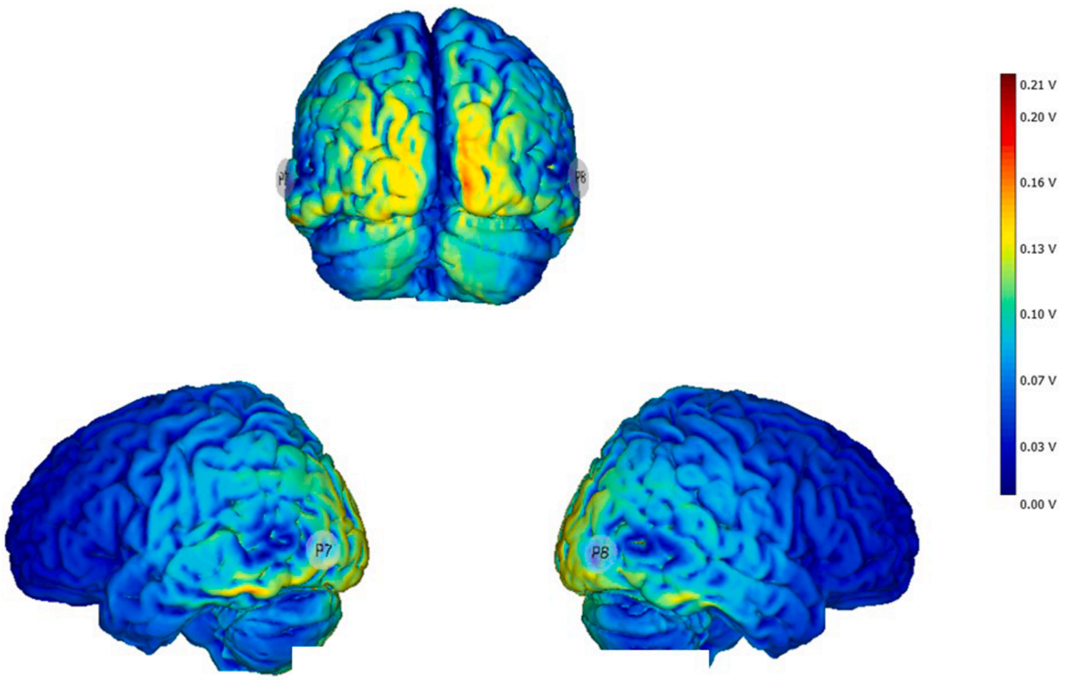

Fig. 2. Back and lateral views of the brain areas stimulated in the experimental group. Simulation was run according to the realistic head model described in Miranda and colleagues (Miranda et al., 2013).

performed a two-blocks face matching task. Stimuli were presented using Psychopy (Peirce et al., 2019) on a 24-inch monitor with a resolution of 1920 × 1080 pixels. Observers seated at approximately 57 cm to the screen. Each trial began with the presentation of a central fixation cross for 500 ms, which was followed by a pair of side-to-side faces. Observers were asked to determine if the pair was an identity match (i.e., both faces depict the same person) or an identity mismatch (i.e., pictures depict two different people), by pressing one of two keys in the keyboard. There was no time limit for the task, and although accuracy was emphasized, observers were instructed to respond as quickly as possible. Observers performed two different blocks. In one of the blocks both faces of the pair were presented in high-resolution, while in the other block one of the faces was pixelated. The order of the blocks was counterbalanced across observers. Each block comprised 30 match and 30 mismatch trials, therefore the whole experiment had a total of 120 trials.

2.5. Design and analyses

Following other face matching studies, accuracy was the dependent variable (Megreya et al., 2011; Megreya & Burton, 2006, 2007; Ritchie & Burton, 2016). We decided to provide stimulation in a between-subject manner (high-frequency tRNS group vs sham group) for several reasons. First, as it is unclear how long the stimulation effects last (see Krause & Cohen Kadosh, 2013), a between-subject design avoids potential carryover effects. Second, using this design, we can also rule out potential learning effects on the task. Additionally, previous studies have shown positive effects of tRNS on face identification in between-participants, but not in within-participants, designs (Penton et al., 2018). Importantly, to avoid spurious differences due to group assignment in the between-subjects design, we selected a high sample of participants and allocated them to each group semi-randomly (e.g., Edmonds & Kennedy, 2017). Stimuli condition (high-resolution, pixelated) and trial type (i.e., identity match vs identity mismatch) were within-subjects factors. This last factor was included as it has been suggested that different processes are involved in telling faces together and telling faces apart (Megreya & Burton, 2007) and it is generally found that experimental manipulations modulate the performance in either mismatch or match trials but rarely in both (Estudillo & Bindemann, 2014; Estudillo & Wong, 2022; Megreya & Burton, 2006, 2007; Ritchie & Burton, 2016). For the analyses, mixed ANOVAs were run. Partial eta-square (η_p^2), as a measure of effect size, and the estimated means and 95 % confidence intervals are also reported. Greenhouse-Geisser correction was applied when the condition of sphericity was not met. JASP (2020) was used for running all the analyses.

3. Results

As can be seen in Fig. 3, the high-frequency tRNS group performed better in both identity match and identity mismatch conditions compared to Sham stimulation group. This was confirmed by a 2 (identity trial type: identity match, identity mismatch) × 2 (stimuli condition: high-resolution, pixelated) × 2 (group: high-frequency tRNS, Sham) mixed ANOVA, which showed a main effect of group [$F(1, 50) = 10.16$, $p < .01$, $\eta_p^2 = .17$], with the high-frequency tRNS group (M = 75.75, CI = 72.96 – 78.55) performing better compared to the Sham stimulation group (M = 69.49, CI = 66.69 – 72.28). The main effect of

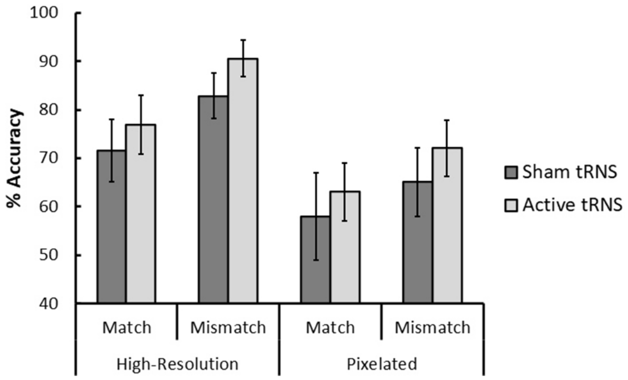

Fig. 3. Percentage matching accuracy for each identity matching condition. Error bars represent 95% confidence intervals.

stimuli condition was also significant [F(1, 50) = 189.68, $p < .001$, $\eta_p^2 = .79$], showing better performance with high-resolution (M = 80.58, CI = 78.31 – 82.84) than with pixelated images (M = 64.66, CI = 62.40 – 66.93). The main effect of identity trial also reached statistical significance [F(1, 50) = 9.14, $p < .01$, $\eta_p^2 = .15$], with observers performing worse in identity match (M = 67.50, CI = 63.60 – 71.39) compared to identity mismatch trials (M = 77.74, CI = 73.85 – 81.64). None of the interactions reached statistical significance [all $Fs(1, 50) \leq 1.38$, $ps \geq 0.2$].

4. General discussion

The main aim of this study was to investigate the effect of tRNS over occipito-temporal cortex on simultaneous face matching performance. Observers received either 20 min 1 mA (100–500hz) tRNS on P7 and P8 sites or Sham stimulation. After this stimulation stage, observers performed a face matching task with high-resolution and pixelated faces. Results showed that observers in the high frequency tRNS group performed better compared to the Sham stimulation group. Interestingly, this effect was evident with both high resolution and pixelated images.

Previous research has produced conflicting results regarding the role of high-frequency tRNS on face identification. For example, although Romanska and colleagues (Romanska et al., 2015) found that participants under the high-frequency tRNS group showed a better performance in the CFPT compared to the Sham stimulation group, Willis and colleagues (Willis et al., 2019) found no differences in performance between high-frequency tRNS and the Sham groups on a perceptual two-alternative forced choice face discrimination task. Moreover, Penton et al. (2018), in a face memory task, found both facilitatory effects in a between-subjects design (Experiment 1) and inhibitory effects in a within-subjects design (Experiment 3). All these studies used a relatively low sample size (36, 39, 38 and 20 participants, respectively), which can limit their conclusions. On the contrary, our study, with more power, supports the modulating role of tRNS for improving face identification.

Another potential reason that could explain the differences in previous results is related to the intensity of the stimulation. In this study, we used 1 mA intensity, following Romanska and colleagues (Romanska et al., 2015). On the other hand, Willis and colleagues (Willis et al., 2019) who showed no effect of tRNS on face perception, delivered an intensity of 1.5 mA. Previous tES research has shown that the effect of stimulation intensity on performance is not completely linear and that different intensities can, indeed, produce opposite effects. For example, Cathodal tDCS is considered to produce cortical inhibition (Nitsche & Paulus, 2000). Interestingly, it has been shown that while 1 mA of cathodal tDCS produces such an inhibitory effect in motor evoke potentials, 2 mA intensity produced excitatory effects (Batsikadze et al., 2013). Thus, how the effect of stimulation intensities modulates visual cognition, in general, and face identification, in particular, is an open question for future research.

This study was run in Malaysia, a largely multi-ethnic society. This is such that in the capital of Malaysia, Kuala Lumpur, 42.3 % of the population is Malaysian-Chinese, 45.2 % Malaysian Malay, 11 % Malaysian-Indian and 1.5 % belong to other minority groups (Department of Statistics Malaysia, 2010). Our observers were all Malaysian national and, although around 63 % of them belong to the Chinese ethnic group, an important number of our observers were Malaysian-Malays and Malaysian-Indians. As our stimuli comprised Chinese ethnic faces, it can be argued that our results could potentially reflect individual differences in the recognition of other-race faces (Wan et al., 2017). However, recent research has shown that, due to the extensive experience with Chinese ethnic faces, Malaysian-Malays and Malaysian-Indian, do not show an other-race effect for Chinese faces (Estudillo et al., 2020, but see Wong, Stephen, & Keeble, 2020). More importantly, our main results remain unaffected not only when Malaysian-Indians and Malaysian-Malays are excluded from the analysis, but also when the analysis only include these two groups (see Supplementary results). This demonstrates that the effects found in this study are race-independent, and therefore our results cannot be explained in terms of individual differences in the identification of other-race faces.

Although it is considered that compared to face recognition face matching relies on a more featural processing approach (Megreya & Burton, 2006; Towler et al., 2017; White et al., 2015), both holistic and featural processing can be used to achieve face identification (Bindemann et al., 2016; Estudillo et al., 2021; Özbek & Bindemann, 2011; Towler et al., 2021). Based on our own results and converging evidence from other studies, we believe that the enhancement after tRNS seen in our study can be explained by an improvement in holistic processing (but see below for an important methodological constrain). Our results show that the effect of high-frequency tRNS was similar across both the high-resolution and the pixelated image conditions. As pixelated faces impairs the discrimination of facial feature discrimination (Bindemann et al., 2013; Lander et al., 2001), our findings suggest that the effect of high-frequency tRNS on face matching must be other than just the improvement of the perception of fine-grained details of the face. Thus, it is possible that the tRNS effects reported in our study are driven by an enhancement of global or holistic processing.

Converging evidence from other studies also suggest that tRNS over occipito-temporal sites enhances holistic processing. For example, a recent report has shown that tRNS over P8 enhanced gender categorization of low-spatial frequency filtered faces (Awasthi, 2022). As holistic face perception is supported by low-spatial frequencies (Goffaux & Rossion, 2006), those results suggest that tRNS enhanced holistic processing of faces. In addition, research in motion perception has shown that high-frequency tRNS facilitates the combination of local components into perceptual wholes (Ghin et al., 2018). More importantly, Romanska and colleagues (Romanska et al., 2015) found that tRNS over P7/P8 improved facial identity perception for upright but not for inverted faces. As inversion disrupt holistic processing of faces, Romanska and colleagues results support that that tRNS over occipito-temporal sites enhanced holistic processing of faces. Future research research should specifically address this question using other holistic face processing measures, such as the composite face or the part-whole tasks (Estudillo et al., 2022; Lee et al., 2022; Rossion, 2013; Tanaka & Simonyi, 2016; Yin, 1969), as research has shown that different measures of holistic processing are largely independent (Rezlescu et al., 2017).

Two important shortcomings of this study should be mentioned. First, in this study we used a between subject design. Although this is the most common design in previous research exploring the effect of electrical stimulation on face identification (Penton et al., 2018; Romanska et al., 2015; Willis et al., 2019), it can be argued that differences between groups were pre-existent and then are not due to the stimulation received. While we cannot rule out this possibility, it is unlikely as a semi-random procedure (aimed to have participants of the same age, gender and ethnicity in each group) was employed to assign participants to each group. Additionally, as we use a high number of participants in each group this reduces the possibility of hazardous differences between groups. Finally, between-subject designs have an important advantage over within-subject designs: by assigning different treatments to each group, carry over effects are avoided (e.g., Edmonds & Kennedy, 2017), and this is especially important in TEs studies as the duration of the post-stimulation effects is largely unknown (Krause & Cohen Kadosh, 2013).

Another important shortcoming of this study is related to the task-specificity effects of tRNS. Specifically, as we compared the active stimulation effects in face matching tasks against sham stimulation, we cannot ensure that the stimulation produced task-specific effects. In other words, it might be the case that simply applying tRNS to any part of the brain increases performance in any visual recognition task. With our current data we cannot answer this question. However, converging evidence from other studies does suggest that tRNS over occipito-temporal sites produce face identification specific effects. For example, using similar stimulation parameters as in our study, Romanska and colleagues (Romanska et al., 2015) found that tRNS over P7/P8 improved facial identity perception facial trustworthiness perception. Interestingly, stimulation over frontal sites did not produce any improvement. These results suggest that the effects of tRNS over temporal sites are both face and anatomical specific.

In conclusion, the results of the present study show that a single session of 1 mA high-frequency tRNS targeted to occipitotemporal sites enhanced face matching performance compared to a Sham stimulation. Participants benefit of this stimulation irrespective of whether faces were presented unaltered or pixelated. Future research should address the neurocognitive mechanisms responsible of these improvements. Our results in conjunction with others (Barbieri et al., 2016; Romanska et al., 2015) do not only open new possibilities for the treatment of face recognition disorders, but have also important potential applications in those scenarios whereby the identification of faces is primordial.

Data availability

Data for the experiment reported here are available upon request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bandc.2022.105937.

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