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Semantic incongruity attracts attention at a pre-conscious level: Evidence from a TMS study

Javier Ortiz-Tudela[*], *Elisa Martín-Arévalo, Ana B. Chica and Juan Lupiáñez*

Department of Experimental Psychology, Centro de Investigación Mente, Cerebro y Comportamiento (CIMCYC), Universidad de Granada, Spain

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ABSTRACT

Unpredicted objects, i.e., those that do not fit in a specific context, have been shown to quickly attract attention as a mean of extracting more information about potentially relevant items. Whether the required semantic processing triggering the attraction of attention can occur independently of participants' awareness of the object is still a highly debated topic. In the present study we make use of a change detection task in which we manipulate the semantic congruity between the to-be-detected object and the background scene. We applied inhibitory repetitive transcranial magnetic stimulation (rTMS) over the right temporo-parietal junction (right TPJ) and a control location (vertex) to test the causal role of the former in the processing of objects at a pre-conscious level. Our results clearly show that semantic congruity can impact detection and identification processes in opposite ways, even when low-level features are controlled for. Incongruent objects are quickly detected but poorly identified. rTMS over the right TPJ effectively diminishes semantic effects on object detection. These results suggest that at least some high order category processing takes place before conscious detection to direct attention towards the most informative regions of space. Moreover, rTMS over right TPJ also impacts object identification, which calls for a re-evaluation of right TPJ's role on object processing.

1. Introduction

When walking down a street on a regular day, our attention is drawn to certain locations of space based on our previous knowledge of the world, on our current goals, as well as on features of the context in which we find ourselves. Our attention gets oriented without our willingness to do so and, most of the time, without even consciously noticing it. Perceptually salient objects such as those with a strong contrast against the surrounding background, or abrupt onsets, easily capture our attention (Corbetta & Shulman, 2002; Ruz & Lupiáñez, 2002; Theeuwes, 1991, 1992). However, objects can be salient not only perceptually but also because they do not fit in their environment. Surprising and unexpected objects are very easily noticeable even when they do

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[*] *Corresponding author*. Department of Experimental Psychology, Centro de Investigación Mente, Cerebro y Comportamiento (CIMCYC), Universidad de Granada, Spain.

E-mail address: fjavierortiz@correo.ugr.es (J. Ortiz-Tudela).

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not have a sudden appearance or when they do not perceptually pop out from their context. For instance, coming across a tiger in our backyard is a highly salient event that will certainly catch our eye, whereas finding that very same tiger on a zoo cage will not do so as prominently. What makes this experience even more interesting is that the *surpriseness* of that object is due to its *semantic* relationship with the context in which it is embedded. Why would a tiger-like object be more surprising in a backyard than in a zoo if not because of our previous knowledge of tigers, backyards, and zoos?

Interestingly, a similar life-like situation can be recreated in the lab by means of a change detection task (Rensink, O'Regan, & Clark, 1997), wherein it has been shown that semantically incongruent changes are detected faster than semantically congruent ones (Hollingworth & Henderson, 2000). For instance, and following the example outlined earlier, when looking at the picture of a backyard, detecting a *dog* takes longer and entails a higher probability of missing it than detecting a *tiger*. This surprising finding shows that some properties of these context-mismatching objects capture attention and eases detection. This result was further extended by LaPointe and colleagues, to show that two processes can be dissociated with this paradigm: context congruent changes impair detection, producing detection costs, though, at the same time, favor discrimination, producing discrimination benefits (LaPointe, Lupiáñez, & Milliken, 2013). LaPointe et al.'s dissociation provides a very useful tool to explore the relationship between several object features (from low-level perceptual ones to high-level semantic ones) as well as visual processes such as visual search (Wolfe, 1994; Yantis & Jonides, 1984), attention allocation (Folk, Remington, & Johnston, 1992; Theeuwes, 1991), or scene encoding (Greene, Botros, Beck, & Fei-Fei, 2015; Peelen & Kastner, 2014).

To date, however, the idea of semantic mismatches attracting attention and biasing access to awareness is still a very hot topic (see e.g., Gray, Adams, Hedger, Newton, & Garner, 2013; Lupyan & Ward, 2013; Rabovsky, Stein, & Abdel Rahman, 2016; Stein, Reeder, & Peelen, 2016; Stein, Siebold, & van Zoest, 2016; Stein & Sterzer, 2012). The existence of these effects somehow demonstrates that semantic processing modulates attentional orienting and, in turn, access to awareness, rather than awareness taking place in the first place, appropriately biasing attention and finally leading to conscious semantic processing.

A widely used model in the study of attentional orienting dynamics is Corbetta and Shulman's (2002) proposal. In their model, the authors argue that while a fronto-parietal dorsal network is in charge of orienting of attention in space, the fronto-parietal ventral network would be responsible for re-orienting attention towards unexpected targets once attention has already been placed somewhere else (see also Corbetta, Patel, & Shulman, 2008; Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005; Macaluso & Doricchi, 2013; Vossel, Geng, & Fink, 2014, for more recent updates of this framework). In particular, within the fronto-parietal ventral network, a specific sub-region of the right posterior parietal cortex (PPC) – the right temporo-parietal junction (right TPJ) – is engaged in processing task-relevant stimuli, particularly when they are unexpected (Geng & Mangun, 2011; Polich, 2007; Verleger, Jaskowski, & Wascher, 2005) or in encoding expectations related to the current environmental and task context (Serences et al., 2005; Vossel, Weidner, Thiel, & Fink, 2009). The right TPJ seems to be more responsive to behavioral/task relevance of stimuli rather than sensory salience *per se* (Indovina & Macaluso, 2007; Kincade et al., 2005). Additionally, right TPJ's activity has been also related to the efficient detection of changes across multiple domains (Downar, Crawley, Mikulis, & Davis, 2000, 2001). Taken together, this evidence suggests that the right TPJ would be implicated not only in the re-orienting of attention by salient objects but generally in the updating of the current context by unexpected and relevant stimuli (Doricchi, Macci, Silvetti, & Macaluso, 2010; Geng & Vossel, 2013).

1.1. *The present study*

In the present study, we further expand our previous work (Ortiz-Tudela, Milliken, Botta, LaPointe, & Lupiañez, 2016) to the neural level to test the causal role of the right TPJ in the processing of categories at a pre-conscious level. We do so by means of the detection/identification dissociation in which context-incongruent objects are detected faster that context-congruent objects but poorly identified. We hypothesize that applying repetitive transcranial magnetic stimulation (rTMS) over the right TPJ would impair participants' ability to quickly re-direct attention in space based on contextual cues, whereas it would not affect discrimination benefits. Our aim is to address two major questions: (1) what is the role of the right TPJ on the unconscious guidance of attention when searching through real-world scenes? and (2) do detection and identification processes involve different cognitive mechanisms with different neural substrates? More specifically, if *detection costs* and *identification benefits* produced by scene semantic congruency are mediated by different systems, recruiting different underlying neural substrates, we would expect the detection cost to be reduced or even eliminated after disrupting activity on the right TPJ (as compared to the vertex disruption), while the identification benefit would remain unaffected.

2. Methods

2.1. *Participants*

A total of twenty-four healthy volunteers, twelve in each group (TPJ group: 7 females, mean age: 26.2-years old; SD = 3.7; vertex group: 4 females, mean age: 26.8-years old; SD = 4.1) from the University of Granada participated in the study in exchange for a monetary compensation (10 Euros/h). All of them completed security protocols for both the magnetic resonance imaging (MRI) and the TMS (Rossi, Hallett, Rossini, & Pascual-Leone, 2009), and signed a consent form approved by the local ethics committee. None of the participants had a history of head injury or physical, neurological, or psychiatric illness. The experiment was conducted according to the ethical standards of the 1964 Declaration of Helsinki (last update: Seoul, 2008). The experiment is part of a larger research project approved by the University of Granada Ethical Committee (175/CEIH/2017).

2.2. *Behavioral task*

On each trial, a rapid alternation of two versions of the same image was presented occupying the totality of the screen. The two versions of the image were identical except for one target object that was digitally added. In between the scenes, a blank screen was included to render the standard flickering appearance (Rensink et al., 1997). Each event (i.e., the two versions of the images and the interleaved blank screens) was presented for 250 msec (see Fig. 1A). Crucially, the identity of the target object could either match (i.e., congruent trials) or mismatch (i.e., incongruent trials) the gist of the surrounding scene. The scenes used were taken from the pool of images used in previous studies (Ortiz-Tudela et al., 2016), and were constructed so that congruent and incongruent objects did not differ in perceptual saliency (Zhang, Tong, Marks, Shan, & Cottrell, 2008). A total of 240 object-plus-background combinations were used throughout the experiment. Half of the entire set ($N = 120$) was assigned to be used for a given participant (60 for the pre-stimulation block and 60 for the post-stimulation block); the other half of the combinations, which was composed of the complimentary versions of the former half, was used for other participants. In other words, for a given participant, each target object was only presented once on either a congruent or and incongruent object–background combination. Object–background congruency, as well as the assignment of each target to either the pre- or the post-stimulation block, was counterbalanced between participants so that across the entire sample each object was seen on every possible combination of congruency and pre–post-stimulation phase.

Participants were required to press the space bar as soon as they noticed a change from one version of the image to the other, even if they were unable to identify the object. Importantly, unbeknownst to the participants, on 10% of the trials the two images were identical, no object was added (catch trials). These trials were included to allow for task performance assessment. This precaution was taken since it has been shown that being aware of the presence of catch trials biases participants' responses (Ortiz-Tudela et al., 2016). After making a response, the alternation stopped, and the image was replaced by a black screen that cued participants to verbally identify the object with one or two words (e.g., "a tiger") or to indicate its approximate location on the screen (e.g., "top left") if identification was not possible (see Fig. 1B). The experimenter registered participants' responses and these were offline coded later on. Emphasis was made on speed for the change detection task.

2.3. *TMS protocol*

Scalp coordinates for the stimulation sites were located by using the native space of each participant's T1-weighted anatomical magnetic resonance scans, acquired for all participants at the Brain, Mind, and Behavior Research Center (CIMCYC) at the University of Granada. We used a 3-T Siemens magnetization prepared rapid gradient echo, flip-angle = 7, repetition time = 2530 msec, echo time = 2.5 msec, slice thickness = 1 mm, Field of View (FOV) = 256 mm. These scans were fed into the Brainsight neuronavigation system (Brainsight, Rogue Systems, Montreal, Canada) to perform a sectional and 3D reconstruction of participants' brains and scalp. The TMS coil was controlled by a robotic arm (TMS Robot, Axilum Robotics) with the capacity to estimate and track in real time the relative position, orientation, and tilting of the coil with a precision of 5 mm. Two regions of interest (ROIs) were stimulated in two different groups of participants: the right TPJ, Montreal Neurological Institute (MNI) coordinates: $x = 53$, $y = -40$, $z = 30$ (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000) as the experimental region; and vertex, MNI coordinates: $x = 0$, $y = -34$, $z = 78$ (Heinen et al., 2011) as the control region. Note that the use of the vertex control was not expected to induce any specific effects based on previous reports (Harris, Benito, Ruzzoli, & Miniussi, 2008; Kalla, Muggleton, Cowey, & Walsh, 2009; Muggleton, Cowey,

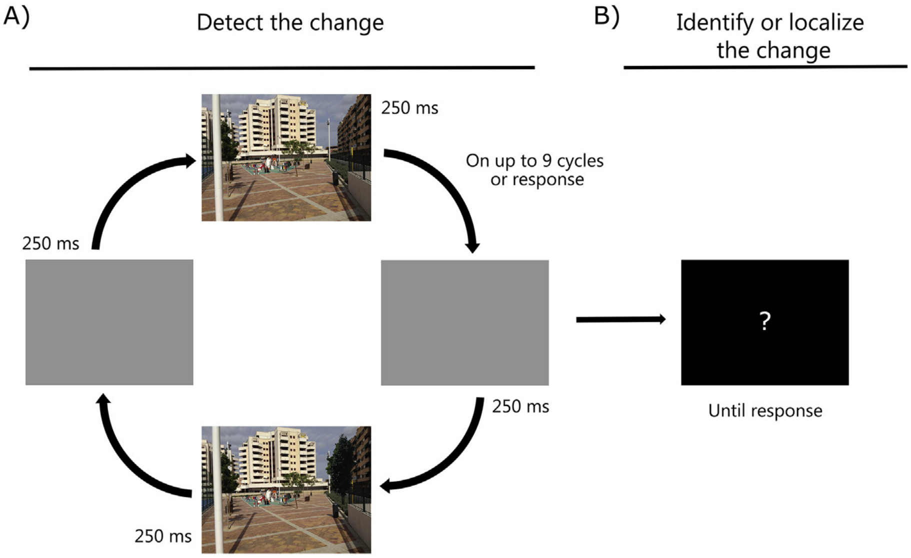

Fig. 1 – Representation of the trial structure. (A) Detection response. (B) Identification response.

& Walsh, 2008). Note also that due to the reduced number of available stimuli for this type of ecological materials and in order to avoid unknown effects of extended practice on participants' strategies a between-participants approach was adopted.

rTMS was delivered by means of a biphasic repetitive stimulator (Super Rapid 2, Magstim, Whitland, UK) and a 70 mm TMS figure-of-eight coil (Magstim, Whitland, UK) positioned at 45° respect to the scalp (Di Lazzaro et al., 1998). rTMS patterns consisted of 1200 pulses applied at 1 Hz with an inter-pulse interval of 1 sec, for a total of 20′. Previous studies have suggested that this protocol transiently reduces cortical excitability in motor regions outlasting for approximately 50% of the stimulation duration (Boroojerdi, Prager, Muellbacher, & Cohen, 2000; Chen et al., 1997; Hilgetag, Théoret, & Pascual-Leone, 2001; Maeda, Keenan, Tormos, Topka, & Pascual-Leone, 2000; Valero-Cabré, Payne, & Pascual-Leone, 2007). The time window of reduced excitability in our study was then estimated in about 10′ – which should cover most of the duration of the post-stimulation block.

We individualized TMS intensity for each participant by stimulating at an intensity of 100% of their resting motor threshold (rMT).[1] Electromyography (EMG) and motor evoked potentials (MEPs) were recorded from the first dorsal interosseous (FDI) of the left hand by using snap surface electrodes (Natus Neurology). The rMT was defined as the minimal intensity of stimulation applied over the primary motor cortex necessary to induce a 50 μV response on 5 out of 10 times (Rossini et al., 2015). The average stimulation intensity for the whole sample was 62% (SD: 6.9) of the stimulator maximum output (MSO). Thresholds were similar for both the right TPJ and vertex groups (right TPJ: 60% MSO, SD = 10.1; vertex: 62% MSO, SD = 4.0).

2.4. *Session structure design*

Each participant completed a pre-stimulation block of 60 change detection trials (approximate duration: 10′), then a stimulation period of 20′, and finally a post-stimulation block identical to the pre-stimulation block (see also Figs. 2 and 3 for a graphical depiction of the session structure). At the end of the session, participants completed a questionnaire regarding the strategies they used to approach the change detection task. In-between periods, experimenters performed the set-up of all the instruments involved, which took approximately 4–5′ on each in-between period, making the total duration of the session to add up to 60 min.

3. Results

For the analysis of mean reaction time (RT), trials in which the target change was missed (8%) and those with correct responses but with RT 4 SD above each participant's mean were excluded (23 observations; 67% of trials). Both a Null Hypothesis Significance Testing and a Bayesian approach were taken for all the analyses.

A first analysis was conducted on the data obtained on the pre-stimulation block to assure that the paradigm produced the expected results and to test for possible between-groups differences before stimulation.

The analysis for detection accuracy (proportion of misses), mean RT, and identification accuracy (% of identification errors) revealed a significant main effect of congruity, $F(1, 22) = 34.83$, $p < .001$, $\eta_p^2 = .62$, BF_{10} (Bayes Factor) = 14,150; $F(1, 22) = 39.49$, $p < .001$, $\eta_p^2 = .64$, $BF_{10} = 10{,}974$; and $F(1, 22) = 36.20$, $p < .001$, $\eta_p^2 = .62$, $BF_{10} = 15{,}480$, respectively. Thus, as expected based on previous findings (Hollingworth & Henderson, 2000; LaPointe et al., 2013; Ortiz-Tudela et al., 2016), longer RT and more misses were observed for congruent than for incongruent trials (see Table 1). The impaired detection for congruent as compared to incongruent trials was even clearer in the combination of these two variables in a *detection efficiency* index (mean RT/detection accuracy), $F(1, 22) = 49.71$, $p < .001$, $\eta_p^2 = .69$, $BF_{10} = 83{,}064$. By contrast, fewer identification errors were made on congruent than on incongruent trials, showing discrimination inefficiency for the former. Note that the two groups were equivalent, as no effect of group or interaction between group and congruency were observed with any of the dependent variables (all $Fs < 1$ and $BF_{10} < .4$).

Since the set-up of the robot and the stimulator took longer than expected (see Fig. 2 for an approximate representation of the timing of the procedure), we analyzed the temporal dynamics of TMS in both groups. An analysis was performed to compare groups' performance on the first half of trials after stimulation and the second half of trials after stimulation, in order to evaluate whether the right TPJ stimulation modulated the observed congruency effect after the stimulation, and whether the modulation occurred across the whole post-stimulation block.

In the first half after the stimulation, the analyses of both mean RT and detection accuracy revealed a reduction in the congruency effect after the right TPJ stimulation (see Table 1), although in neither case the group × congruency interaction was significant, $F(1, 22) = 1.76$, $p = .198$, $\eta_p^2 = .04$, $BF_{10} = .7$; and $F(1, 22) = 1.46$, $p = .240$, $\eta_p^2 = .04$, $BF_{10} = .8$. Nevertheless, combining these two measures in the *detection efficiency* index showed that the congruency effect was marginally reduced in the right TPJ stimulation group as compared to the vertex group, $F(1, 22) = 3.66$, $p = .069$, $\eta_p^2 = .14$, $BF_{10} = 2$ (see Fig. 2). Unexpectedly but interestingly, the results also showed a significant interaction between group and congruency in identification errors, $F(1, 22) = 6.33$, $p = .020$, $\eta_p^2 = .15$, $BF_{10} = 3.29$ in the first half after the stimulation period. The vertex stimulation group showed a significant effect of congruency, $F(1, 22) = 19.71$, $p < .001$, $\eta_p^2 = .66$, $BF_{10} = 117.7$, with more errors for incongruent than for congruent trials. In sharp contrast, the congruency effect was completely absent in the right TPJ stimulation group ($F < 1$, $BF_{10} = .33$). To further explore this unexpected result, a repeated measures Analysis of Variance (ANOVA) was performed for each group with phase (pre-stimulation *vs* first half post-stimulation) and congruency (congruent *vs* incongruent) as within-subjects factors. The analysis of the vertex group showed the congruency effect was not significantly different before (15%) and after stimulation (17%, $F < 1$, $BF_{10} = .40$). Conversely, in the right TPJ stimulation group, the

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[1] Higher intensities induced facial sensations, involuntary blinks, or jaw movements.

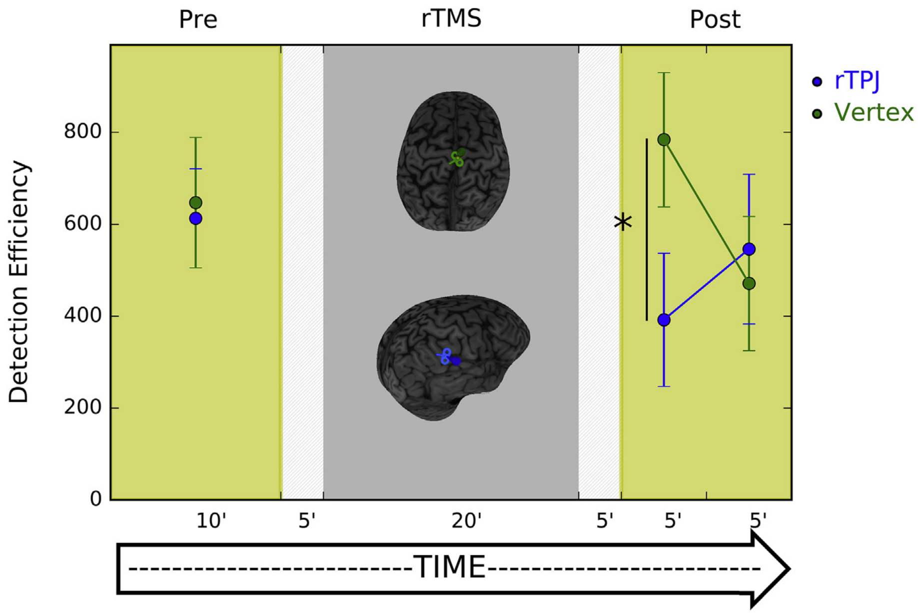

Fig. 2 – Congruity effect (congruent–incongruent) on efficiency index for the two stimulation conditions (right TPJ, in blue; and vertex, in green). The relevant phases for task analysis are, from left to right, before stimulation (10′), first block after stimulation (5′), and second block after stimulation (5′), with an approximate 4–5′ preparation delay between the end of the stimulation and the beginning of the post-stimulation phases. A 3D representation of the two areas of stimulation is included.

effect was significantly reduced after stimulation (3%) as compared with the pre-stimulation block (13%), $F(1, 11) = 9.37$, $p = .011$, $\eta_p^2 = .46$, $BF_{10} = 73$ (see Fig. 2). Interestingly, post-hoc Tukey comparisons revealed that the reduction in the congruency effect was due to better identification of incongruent objects in the post-stimulation block when compared with pre-stimulation one ($p = .036$). In other words, identification for context-incongruent objects was improved after rTMS over the right TPJ but not over the vertex.

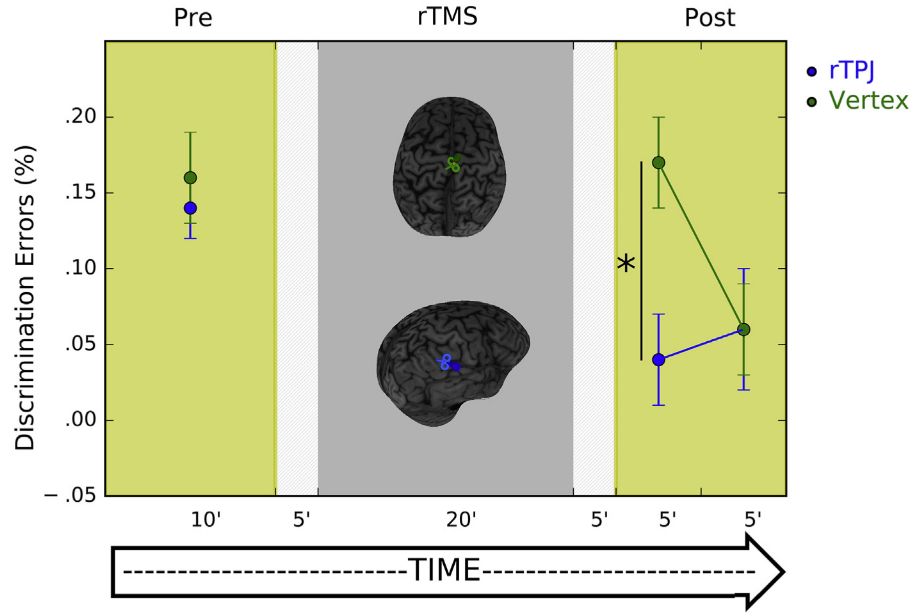

Fig. 3 – Congruity effect on identification errors (incongruent–congruent) for the two stimulation conditions (right TPJ, in blue; and vertex, in green). The relevant phases for task analysis are, from left to right, before stimulation (10′), first block after stimulation (5′), and second block after stimulation (5′), with an approximate 4–5′ preparation delay between the end of the stimulation and the beginning of the post-stimulation phases. A 3D representation of the two areas of stimulation is included.

Table 1 – Mean RT and percentage of accurate detection responses (in parenthesis) for object detection, and percentage of accurate responses for object identification, for each experimental condition on each phase of the experiment (pre- and post-stimulation and halves in the post-stimulation block).

ROI	Object detection						Object identification					
	Pre		Post				Pre		Post			
	C	I	1st Half		2nd Half		C	I	1st Half		2nd Half	
			C	I	C	I			C	I	C	I
TPJ	2067 (.87)	1699 (.96)	1858 (.88)	1612 (.94)	1958 (.91)	1492 (.93)	.80	.67	.82	.79	.85	.79
Vertex	2199 (.88)	1828 (.96)	2349 (.88)	1859 (.98)	1912 (.91)	1614 (.97)	.85	.70	.88	.71	.84	.77

Note: C (congruent), I (incongruent).

In the second half after the stimulation, the analysis showed again a main effect of congruency in mean RT, $F(1, 22) = 20.01$, $p < .001$, $\eta^2_p = .46$, $BF_{10} = 325$; *detection efficiency*, $F(1,22) = 21.61$, $p < .001$, $\eta^2_p = .49$, $BF_{10} = 643$; and identification errors, $F(1, 22) = 4.42$, $p = .047$, $\eta^2_p = .17$, $BF_{10} = 2$. The effect was absent in detection accuracy, $F(1, 22) = 2.37$, $p = .13$, $\eta^2_p = .10$, $BF_{10} = 1$. Finally, the group factor did not modulate the effect of any other dependent variables (all $Fs < 1$ and $BF < .8$).

To sum up, the right TPJ stimulation seemed to eliminate or reduce the effect of congruency, although the effect was only significant with identification errors, marginally significant with *detection efficiency*, and only lasted for approximately 10′ reaching about half of the trials after stimulation. Caution is needed when drawing strong conclusions, however, since we acknowledge that the split-half analysis was performed based on procedural reasons and not on statistical ones. Exhaustive replication of these data is essential to consolidate the findings reported here.

4. Discussion

The aim of this study was to explore the interplay between unconscious semantic processing and attentional allocation during scene viewing at the neural level. We did so by applying offline inhibitory rTMS combined with a change detection task with context-congruent and context-incongruent target objects. We compared participants' performance before and after stimulation with an active vertex control group. Right TPJ activity has been related to attentional orienting/re-orienting (Bourgeois, Chica, Valero-Cabré, & Bartolomeo, 2013; Corbetta et al., 2000) and contextual updating (Doricchi et al., 2010; Geng & Vossel, 2013). We therefore hypothesized that this region would be important for target *detection*.

Our *pre-stimulation* results appropriately replicated the two processes dissociation of object perception (LaPointe & Milliken, 2016; LaPointe et al., 2013; Ortiz-Tudela et al., 2016) ensuring that semantic processing of the scene was effectively biasing attention allocation towards the most informative region of space – i.e., attention was attracted to semantically incongruent objects. These results demonstrate that some form of semantic processing must take place before conscious access, at least at the category level. Indeed, since we controlled for low-level differences in saliency (Zhang et al., 2008) between congruent and incongruent trials, the most plausible cause for the asymmetrical behavioral patterns in detection and identification tasks is the semantic fitness of the object with its surrounding context. However, in order to notice a specific object–context mismatch it is enough to access its belonging category and contrasting it to the gist of the surrounding scene. In other words, it suffices to know that an item is an animal-like object to notice that it does not belong in a city-like environment.

Our *post-stimulation results* show an interaction between the region of stimulation and the target–context combination for both object detection and – unexpectedly – object identification. This interaction will be described and discussed in the following sections.

4.1. *Right TPJ's involvement in object detection/identification*

Activity in the right TPJ has been correlated (Corbetta & Shulman, 2002; Vossel et al., 2014) and causally related (Chica, Bartolomeo, & Valero-Cabré, 2011) to attentional performance in a wide range of tasks in healthy populations. Evidence from clinical patients also suggests that its proper functioning is critical for an appropriate attentional allocation. For instance, studies in neglect patients (Bartolomeo & Chokron, 2002; Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005; Posner, Walker, Friedrich, & Rafal, 1984) have supported the role of the right TPJ in spatial attention by showing an impaired ability to adequately shift attention toward regions of a scene located contralaterally to the brain lesion (Bartolomeo, Thiebaut de Schotten, & Chica, 2012).

Interestingly, it has been reported that when looking at pairs of objects, neglect patients tend to miss the object placed contralaterally to the lesion, which is known as *extinction*. This deficit is especially pronounced when the stimulus presented in the ipsilateral field shares the same meaning and elicits the same action as the one presented on the contralateral field (Baylis, Driver, & Raeal, 1993; Bender & Furlow, 1945; Rafal, Danziger, Grossi, Machado, & Ward, 2002). In other words, extinction refers to a *cost* in detecting a particular item especially when it shares some specific features with a competing one; this cost can be overridden when the two objects' features mismatch. Although evidence for this effect is sparse, it suggests that a representation of the two objects and their attached responses can be established unconsciously and is capable of biasing attention allocation, modulating conscious access.

Our study deepens in this idea by showing that temporally inhibiting right TPJ's activity with rTMS hinders efficient incongruent-object detection. Indeed, when contrasting rTMS over the right TPJ versus the vertex, the former critically reduces the congruity effect on detection efficiency. Although caution is needed when drawing conclusions from this interaction since we did not obtain strong statistical support – most likely due to not having enough statistical power – the fact that the uncovered pattern follows our a priori predictions and is in line with previous literature supporting the involvement of right TPJ in object detection (Corbetta et al., 2000; Kincade et al., 2005) makes it worth considering. Besides, this result also extends previous findings since it is, to our knowledge, the first demonstration of the right TPJ's involvement in attentional (re-)orienting associated with a semantic incongruity. It is also worth noting, however, that on a different field of research, the right TPJ's activity has been related to humor processing (Bekinschtein, Davis, Rodd, & Owen, 2011; Samson, Hempelmann, Huber, & Zysset, 2009), especially when a semantic incongruity resolution is involved in the joke (Chan & Lavallee, 2015).

More interestingly, our results also show that rTMS over the right TPJ causes a reduction in the congruity effect for *identification scores*. This unexpected finding calls for a reanalysis of the assumed role of the right TPJ in object processing (Doricchi et al., 2010). Consistently, Doricchi et al.'s proposal challenges the relationship between right TPJ's activity and object detection (see also Geng & Vossel, 2013; Macaluso & Doricchi, 2013, for updated versions of this proposal). The authors argue that the set of – sometimes contradictory – evidence on right TPJ's activity can be better accommodated by an account that signals contextual updating as the main function of this region. They argue that post-perceptual processes and readjustments of top-down expectations are much better candidates since (1) the right TPJ responds to target appearance later than other brain regions such as frontal eye fields (Meister et al., 2006; Mohler, Goldberg, & Wurtz, 1973) and (2) the left TPJ also responds to target object onsets but does so for those that match expectations and those that do not, whereas right TPJ only responds for expectation-mismatching ones (Doricchi et al., 2010). This proposal is congruent with the idea that the right TPJ may encode expectations regarding the relationship between a sensory stimulus and the context-appropriate action (Downar et al., 2001; Geng & Mangun, 2011).

The results reported here can complement this new framework by assuming that context (or expectation)-mismatching objects might require a re-evaluation of the initial gist of the scene, recruiting the right TPJ. This re-evaluation would, in turn, act as circuit breaker for the identification process, stopping it from developing any longer and leading to a poor identification. Complimentarily, this abrupt stopping of the identification process would allow a fast response of the detection one. Therefore, we argue – while speculative – that in the experiment reported here rTMS over the right TPJ would prevent the abortion of the identification process which would improve identification scores for context-mismatching objects at a cost on their detection (Doricchi et al., 2010; Geng & Vossel, 2013; Macaluso & Doricchi, 2013). Note in Table 1 that the lack of congruency effect after rTMS over right TPJ is not due to any hindering effect on the congruent condition after stimulation (.80 before *vs* .82 after stimulation), but to a recovery in the incongruent condition (.67 before *vs* .79 after stimulation). Thus by stimulating the right TPJ, rather than hindering identification performance on congruent trials what seems to be happening is that identification of incongruent trials is improved by preventing the abandonment of the identification process. Future research, perhaps with a comparison between rTMS over both right and left TPJ, would help clarifying the specific role of right TPJ and disentangling the interaction between pure object detection and semantic incongruity processing. In addition, an exhaustive exploration of the temporal involvement of the right TPJ in the present task would provide very interesting information. Indeed, two different types of TPJ's activity have been shown to underlie contextual updating. One of them is related to preparatory orienting of attention (Doricchi et al., 2010; Shulman, Astafiev, McAvoy, D'Avossa, & Corbetta, 2007; for corresponding event-related potential evidence see, Lasaponara et al., 2017; Lasaponara, Chica, Lecce, Lupianez, & Doricchi, 2011) and the other one reflects a specific activation for context-mismatching targets (Geng & Mangun, 2011). In the present study, it is impossible to distinguish the separate contribution of each of them and the consequences of disrupting one or the other since the repetitive offline protocol likely suppresses both of them. An online stimulus-locked study would offer valuable information into which one of the two types of activity is crucial for object detection and object identification in ecological set-ups.

In the next section, we further discuss the implication of the present set of results at the cognitive level for the two processes involved (i.e., object detection and object identification) and offer an alternative explanation for the unexpected identification pattern.

4.2. *Two processes fully dissociated?*

The classical temporal dynamics of object detection and object identification reports tells us that the former necessarily occurs *before* the latter (Holender, 1986). However, whether they constitute two independent processes or two sides of the same general object-processing coin is still to solve (LaPointe & Milliken, 2016; Ortiz-Tudela et al., 2016; Stein & Peelen, 2015). The rTMS approach used here attempted at affecting one of them without impairing the other. As noted before, while the right TPJ's involvement in object detection has been previously reported (Corbetta et al., 2000; Natale, Marzi, Girelli, Pavone, & Pollmann, 2006; Shulman et al., 2009), its relation with object identification is not so clear (but see Marois, Leung, & Gore, 2000; Geng & Vossel, 2013). Here, we show that rTMS over the right TPJ impacts both object detection and object identification, as the congruity-mediated dissociation was equally modulated by the disruption of the right TPJ's activity. Does this result mean that detection and identification processes are not fully dissociable? In our opinion, it does not. What it does is to soften the distinction between the two and to point at the fact that, even if independent, the two processes need to closely interact with each other.

In our framework this result can be interpreted as two independent but interactive processes influencing each other by means of shared operations (and neural substrates) such as contextual elaboration, object segregation, or schema completion. While regions more specialized on object detection and object identification could be located somewhere else in the brain (Bar et al., 2001; Malach et al., 1995), the right TPJ would be a common hub for these two processes – see section above. Thus, we need to consider more complex models of scene processing than just two independent sequential processes (Marois et al., 2000). Probably both object detection and object identification engage into interactive dynamics in the sense *predictive coding* models propose: feedforward connections modulate object identification from object detection and conversely, feedback relations bias object detection from the accumulative knowledge acquired through recursive partial-identification (Rao & Ballard, 1999; Summerfield et al., 2006). Several of these iterations would be necessary for information to (resonate and) access consciousness. However, as it has been shown in the present set of results, pre-conscious recursive scene processing would be able to appropriately guide attention towards certain regions of a given context.

Finally, it is worth noting that analyses of the post-stimulation data on the right TPJ TMS group revealed that identification levels for context-incongruent objects were brought up to context-congruent levels. This result also calls for a re-evaluation of the explanation given to the congruity effect on identification (LaPointe et al., 2013; Ortiz-Tudela et al., 2016). It has been previously argued that the differential performance on identification of congruent and incongruent objects could be explained in terms of semantic priming from the gist of the background scene to the identity of the object. This priming influence would be beneficial only for context-congruent objects thus rendering the previously observed pattern both in online reports and offline delayed memory test (LaPointe et al., 2013; Ortiz-Tudela et al., 2016). However, this account would have problems explaining why inhibiting activity on the right TPJ would boost incongruent object identification. Here, we speculate in two different alternatives that should be tested in future studies: (1) in standard situations, the identification process is gradually performed by building up the meaning of the available targets. When an incongruity is found, this process is aborted in favor of a rapid and unspecific conscious detection. Inhibiting activity in the right TPJ would prevent this abortion thus allowing the identification process for incongruent targets to reach that of congruent targets based solely on object information; (2) the inability to properly use contextual cues to facilitate identification would come from the setting up of a contextual schema that would not ease (at least not only) the identification of new schema-congruent objects but which would also inhibit or impair – through implausibility discard or erroneous inferences – schema-incongruent objects (see Van Kesteren, Ruiter, Fernández, & Henson, 2012, for a similar reasoning on memory formation for schema-incongruent objects). Therefore, preventing this schema-formation would allow incongruent objects to be properly identified. Future research is needed to fully understand this pattern of results.

5. Conclusions and future directions

Whether attention can be drawn unconsciously to specific objects that semantically mismatch a particular scene is a very interesting and still highly debated topic. In the present paper we offer evidence from an ecologic paradigm of semantic processing taking place prior to conscious access that effectively biases attention. In addition, our results further extend previous research pointing at the relevant causal role that the right TPJ has on attentional orienting driven by semantic incongruity showing that one can successfully reduce attentional effects by inhibiting activity in that area. Future research is needed to further extend these results by exploring the temporal dynamics of the right TPJ's involvement in object processing. Does TPJ act right after the detection of the incongruity takes place? Does it have any partial role in the processing of the incongruity itself? How does it interact with object identification? All these questions will provide important information about the interplay between attention and pre-conscious processing.

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