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The neural correlates of abstract versus concrete words: Evidence from an rTMS study

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Introduction

Several neuroimaging studies have shown that concrete word processing, relative to abstract word processing, produces greater activation in a bilateral network of associative areas, including temporal, parietal and prefrontal cortex, while processing of abstract words produces greater activation almost exclusively in the left superior temporal and inferior frontal cortex, both when using a semantic similarity judgment task on concrete and abstract noun triads (Sabsevitz, Medler, Seidenberg, & Binder, 2005), or synonym judgments (Noppeney & Price, 2004). A different pattern (concrete area on the left and abstract one on the right) has been observed in a PET study (Whatmough, Verret, Fung, & Cherktow, 2004), in which concrete and abstract concepts were directly opposed (abstract minus concrete).

In the case of neuropsychological studies, a patient has been described with a reversal of the concreteness effect and a hypoperfusion of the inferior temporal gyrus (ITG), particularly on the left side (Breedin, Saffran, & Coslett, 1994).

In the present study we further investigate the role of the ITG in processing abstract and concrete words, by means of repetitive magnetic transcranial stimulation (rTMS).

Materials and method

Eighteen healthy right-handed Italian participants (14 women and 4 men, mean age 22.2, mean educational level 14.3) took part in the experiment. An odd-one out paradigm was used. The test included 60 (30 abstract and 30 concrete, matched for frequency) noun triplets, randomly intermingled. In a preliminary study a list of abstract and concrete words was created. Thirty-two subjects were asked to rate the degree of abstractness/concreteness of each word by assigning a score ranging from 0 to 5, where 0 meant "absolutely abstract" and 5 "absolutely concrete". Those words, which were rated 0 or 5, respectively, by at least 75% of the subjects, were selected. Participants were presented with three words and asked to indicate the one that was least related in meaning, by pressing one of three buttons on the keyboard. Each triplet was visually presented for 3000 ms: rTMS was applied after 1500 ms at 5 Hz, at 100% of individual motor threshold. Two sites were stimulated: left (L) and right (R) ITG. The location of the stimulation sites was on average centred on Talairach co-ordinates $X = -50$, $Y = -54$, $Z = -5$; and $X = 50$, $Y = -57$, $X = -11$, respectively (Talairach & Tournoux, 1988). The experiment was run in three blocks, corresponding to the two stimulated scalp positions and a baseline without rTMS. The stimuli for each block were chosen based on a pilot experiment performed with 20 participants (different from those recruited for the main study) to balance the mean response time across the blocks. The order of stimuli within each block and the order of blocks were randomized and counterbalanced across participants. Accuracy and reaction times were measured.

Results

An ANOVA for repeated measures was performed on mean RTs and number of correct responses, with word type (two levels: abstract versus concrete) and condition (three levels: baseline, LITG and RITG) as within subject factors. RTs were excluded from the analysis if the subjects responded incorrectly or if RTs were lower than 400 ms.

Regarding accuracy (see Fig. 1) the main effect of condition was significant [$F(2,34) = 3.9$, $p < .003$], with a higher number of errors when rTMS was applied over the RITG; word type was also significant [$F(1,17) = 5{,}1$, $p < .004$], with participants producing more errors with abstract than concrete items. However, in the baseline condition no significant difference was found in performance between abstract and concrete triplets. The interaction between condition and word type was also significant [$F(2,34) = 4.2$, $p < .003$]. Post-hoc analyses showed that rTMS applied over the RITG significantly reduced the number of correct responses in the case of abstract words compared to rTMS applied over the LITG ($p < .001$) and to the baseline ($p < .02$). In the case of concrete words, performance did not differ in the three conditions. rTMS applied over the RITG significantly reduced accuracy for abstract words compared to the concrete ones ($p < .001$), while there was no difference between abstract and concrete words when rTMS was applied over the LITG and, as already mentioned, in the baseline.

Regarding RTs, there was no significant effect of condition and word type, nor the interaction was significant.

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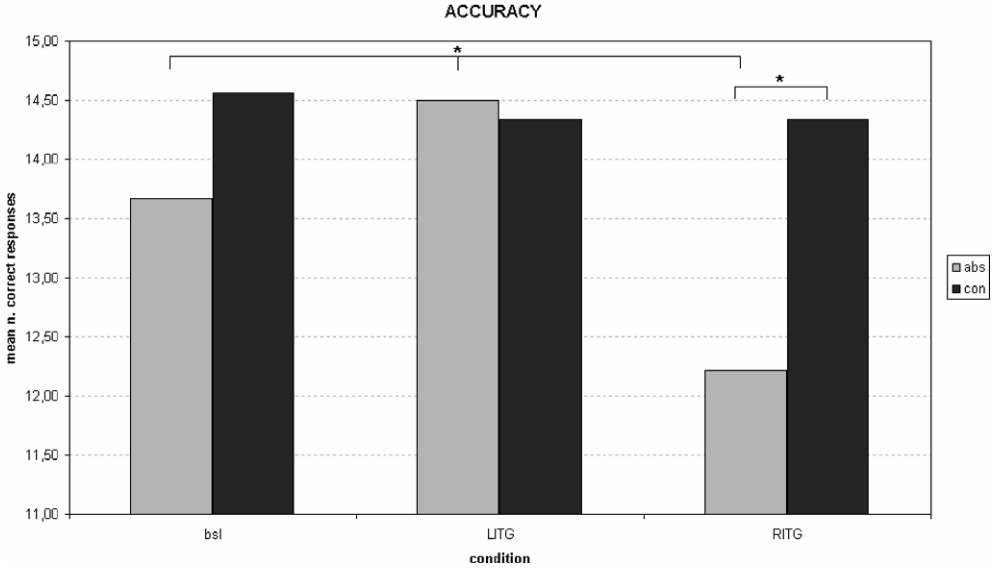

Fig. 1. Mean of correct responses for abstract and concrete words. *Significant differences: bsl, baseline; LITG, left inferior temporal gyrus; RITG, right inferior temporal gyrus.

Conclusion

This experiment suggests that right hemisphere structures located in the ITG are involved in processing abstract terms, but are not critical for the processing of concrete words. Further studies need to be performed in order (i) to assess the role of additional sites, such as the left superior and inferior frontal gyri, as suggested by the neuroimaging literature, and (ii) to confirm these preliminary results.

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