Supporting Information

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SI Results

Reaction Times. Effects that did not interact with transcranial magnetic stimulation (TMS) group as revealed by the ANOVA comparing the effect of real vs. sham TMS were as follows: There was a main effect of TMS laterality ($F_{2,50}$ = 5.74; P = 0.006) because reaction times (RTs) were slower when real or sham TMS was bilateral compared with left only (t_{27} = 3.35, P = 0.001) or right only (t_{27} = 2.34, P = 0.021) but this did not interact with task or group (all $P > 0.45$). There was also a main effect of stimulus modality ($F_{1,25}$ = 586.97, P = 0.0001) because RTs were slower in the auditory than visual conditions, and a main effect of task ($F_{1.34,33.41}$ = 16.39, P = 0.0001) because RTs were slower for phonological compared with semantic (t_{27} = 5.70, P = 0.0001) or perceptual (t_{27} = 4.34, P = 0.0001) decisions. The effect of phonological relative to semantic decisions was highly significant in both the auditory (t_{27} = 4.56, P = 0.0001) and visual (t_{27} = 3.54, P = 0.001) modalites, but an interaction between task and modality ($F_{1.54,38.52}$ = 13.17, P = 0.0001) arose because the difference between phonological and perceptual decisions was greater in the visual modality (t_{27} = 4.91, P = 0.0001) than the auditory modality (P = 0.093). In the visual modality, RTs were faster to perceptual than semantic decisions (t_{27} = 3.07, P = 0.005), but in the auditory modality RTs were faster to semantic than perceptual decisions (t_{27} = 4.87, P = 0.0001). Across modalities, these effects resulted in a trend for longer RT in the perceptual relative to the semantic task (P = 0.09).

Unpleasantness Scores. There were no significant differences in the real TMS group between preexperimental ratings (mean: 1.5, 1.5, 2.0; SD: 0.65, 0.52, 0.88 for left, right and bilateral stimulation, respectively) and postexperimental ratings (mean: 1.5, 1.36, 1.93; SD: 0.65, 0.50, 0.83) (all $P > 0.32$). However, bilateral stimulation was significantly more unpleasant than left or right stimulation, both preexperimentally (Z = 2.65, P = 0.016 compared with left stimulation and Z = 2.33, P = 0.031 compared with right stimulation) and postexperimentally (Z = 2.45, P = 0.031 compared with left and Z = 2.31, P = 0.035 compared with right TMS). All subjects in the sham TMS group rated the three different sham TMS conditions as neutral (i.e. "1"). Thus, real TMS was significantly more unpleasant than sham TMS in all conditions (Z = 3.86, Z = 3.87, Z = 5.43, all P = 0.0001 for left, right, and bilateral stimulation pooled over pre- and postexperimental ratings, respectively).

SI Materials and Methods

Stimuli. We used 120 German words for stimulus presentation. Only highly frequent, unambiguous nouns from the CELEX lexical database for German (Centre for Lexical Information, the Max Planck Institute for Psycholinguistics, The Netherlands) were selected. All words represented natural or man-made items (50% each).

Thirty German native speakers (15 females, age 24–47, mean age 29.0) independently categorized each item as either man-made or natural, rated each item's image-ability on a four-point scale, ranging from 1 (concrete) to 4 (abstract), and provided the number of syllables for each item. These subjects were not included in the present study.

Only those words that (*i*) at least 29 out of 30 pilot subjects correctly classified as being either man-made or natural, (*ii*) received an average imageability rating of < 1.6, and (*iii*) reached > 90% agreement on the intended syllable count were included. Because more two-syllable than three-syllable words passed the above validation criteria, we were able to select the two-syllable nouns that most closely matched the three-syllable words in terms of their image-ability ratings and number of letters (to the degree possible). In total, 60 two-syllable nouns and 60 three-syllable nouns were selected. All words represented natural or man-made items (50% each).

One half of the auditory stimuli were manipulated using the sound program Adobe Audition 2.0 such that there was an audible yet unobtrusive decline (13 halftones) in vocal pitch toward the end of the word. In analogy to the auditory condition, the font size was manipulated for half of the visual stimuli such that it changed from an initial 86 points in 1-point steps across the length of the word, to result in a noticeable yet unobtrusive change in the visual appearance of the word. Auditory versions of the words were recorded by a professional female speaker and had an average duration of 0.74 s (range: 0.52–1.02 s, two-syllable words) or 0.87 s (range: 0.66–1.12 s, three-syllable words), respectively.

Procedure. To allow for neuronavigated TMS, all subjects underwent MRI using an MPRage sequence in sagittal orientation (slice thickness 1 mm; in-plane resolution 1 × 1 mm; TE/TR = 3.78/8.25 ms). After stereotactic coregistration and determination of the individual motor threshold with TMS over the left motor cortex, the experiment was explained and subjects performed a training session with three trials per task. None of the stimuli used in that session were repeated in the main experiment. During the practice session, sound volume was individually adjusted for each subject (with a range of 100–105.8 decibels). Auditory stimuli were presented via in-ear headphones equipped with earplugs to shield the subject from the TMS-induced noise. For further shielding, a foam cushion was fixed around the subject's head above the ears during the whole procedure. During volume adjustment, TMS coils were charged closely above the subject's head to induce noise that was comparable to the experimental session. Visual stimuli were presented in the center of a computer monitor in front of the subject (19-inch flat-screen monitor, resolution: 1,280 × 1,024 pixels; distance from the subject: 70 cm). The font size for presentation was set to an initial 86 points.

Transcranial Magnetic Stimulation. Neuronavigated TMS was preinformed by using the stereotactic coordinates for left supramarginal gyri (SMG) across previous studies comparing visually presented words in a comprehension task (1–3) (x, y, z = −45, −39, 45 mm). Sterotactic coordinates for left angular gyrus (ANG) (x, y, z = −42, −66, 28 mm) were obtained from the comparison of the semantic to the phonological task in Devlin et al. (1). For TMS of right SMG and ANG, we used the homolog coordinates in the right hemisphere (x, y, z = 45, −39, 45 mm; x, y, z = 42, −66, 28 mm).

The individual stimulation sites were then determined by calculating the inverse of the normalization transformation and transforming the coordinates from standard MNI space to "individual" space for each subject. A recently developed algorithm (http://rniftilib.r-forge.r-project.org/) calculated the shortest distance from the target coordinate in the brain to the surface for each subject. The TMS coils were placed over these "entry-coordinates" on the surface of the head.

Stimulation intensity was corrected for the difference in the scalp-cortex distance between the motor cortex and the SMG using a simple linear correction. Therefore, the location of the motor cortex (M1) was determined by using the same algorithms as described above. The average Montreal Neurological Institute coordinates for the M1 were taken from a recent meta-analysis (4).

For the distance correction, we adapted the following formula recommended by Stokes et al. (5):

$$AdjMT\% = MT + 3(D_{SMG} - D_{M1})$$

where AdjMT% corresponds to the adjusted motor threshold in percentage stimulator output, MT is the unadjusted MT in percentage stimulator output, D_{SMG} is the distance between scalp and target in the left or right SMG, and D_{M1} corresponds to the distance between scalp and target in the motor cortex. The difference in the distance between the two sites is multiplied by 3 to account for the spatial gradient relating MT to distance (5). Because this correction would have resulted in very high and thus unpleasant stimulation intensities for most of the subjects, we used 90 instead of 100% of MT for the correction, corresponding to our TMS protocol [90% resting motor threshold (RMT)]. Corrected mean-stimulation intensity was 44.5 ± 5.83% total stimulator output; adjusted RMTs for the left and right SMG were not significantly different.

The RMT was defined as the lowest stimulus intensity that elicited at least five visible twitches in 10 consecutive stimuli given over the motor hot spot. Figure-eight-shaped coils (double 90 mm; coil type Q.C., Mag and More GmbH) and P-Stim 160 stimulators (Mag and More GmbH) were used in all TMS conditions. The coils were positioned with the handle pointing lateral and perpendicular to the midline over the left and right SMG, with the second phase of the biphasic pulse inducing a lateral to medial current flow.

We used frameless stereotaxy (TMS-Navigator, Localite) based on the coregistered individual T1-weighted MR image to navigate the TMS coils and maintain their exact location and orientation throughout the experimental sessions.

In the sham TMS group, an additional coil was placed in an angle of 90° over each coil. Stimulation intensity of these coils was set 15% higher to create a comparable acoustic stimulus without stimulating the brain. Trials with sham stimulation over the left, right, or bilateral SMG (40 each) were pseudorandomly intermingled.

Data Analysis. For the effect of real vs. sham TMS over the left, right, and bilateral SMG, RTs were examined with a $2 \times 3 \times 3 \times 2$ repeated-measures ANOVA, including a between-subjects factor group (real TMS vs. sham TMS) and the within-subject factors task (phonological, semantic, perceptual), TMS laterality (left, right, or bilateral) and modality (auditory vs. visual). For the effect of real TMS over SMG vs. ANG, RTs were examined with a four-way repeated-measures ANOVA, including the within-subject factors region (SMG vs. ANG), task (phonological, semantic, perceptual), TMS laterality (left, right, or bilateral) and modality (auditory vs. visual). ANOVAs only included trials with correct responses. All statistical analyses were performed with SPSS (version 13).

1. Devlin JT, Matthews PM, Rushworth MF (2003) Semantic processing in the left inferior prefrontal cortex: A combined functional magnetic resonance imaging and transcranial magnetic stimulation study. *J Cogn Neurosci* 15:71–84.
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4. Mayka MA, Corcos DM, Leurgans SE, Vaillancourt DE (2006) Three-dimensional locations and boundaries of motor and premotor cortices as defined by functional brain imaging: a meta-analysis. *Neuroimage* 31:1453–1474.
5. Stokes MG, et al. (2005) Simple metric for scaling motor threshold based on scalp-cortex distance: Application to studies using transcranial magnetic stimulation. *J Neurophysiol* 94:4520–4527.

Table S1. RTs and ER for the different tasks in the real TMS group and the sham TMS group

	Auditory stimuli		Visual stimuli	
Task/TMS	RTs (ms) ± SEM	ER(%) ± SEM	RTs (ms) ± SEM	ER (%) ± SEM
Group receiving real TMS (*n* = 14)				
Phonological				
Left	1,223 ± 48.07	0.10 ± 0.02	814 ± 49.00	0.11 ± 0.02
Right	1,216 ± 49.93	0.09 ± 0.03	820 ± 49.24	0.08 ± 0.02
Bilateral	1,252 ± 48.62	0.11 ± 0.02	826 ± 44.30	0.09 ± 0.02
Semantic				
Left	991 ± 27.41	0.03 ± 0.01	699 ± 26.52	0.04 ± 0.01
Right	1,026 ± 25.56	0.03 ± 0.01	704 ± 27.75	0.05 ± 0.02
Bilateral	1,014 ± 23.00	0.03 ± 0.01	705 ± 22.48	0.05 ± 0.01
Perceptual				
Left	1,113 ± 27.00	0.14 ± 0.03	673 ± 20.99	0.14 ± 0.02
Right	1,105 ± 24.69	0.14 ± 0.04	662 ± 25.01	0.12 ± 0.03
Bilateral	1,142 ± 25.95	0.14 ± 0.03	674 ± 22.65	0.13 ± 0.03
Group receiving sham TMS (*n* = 14)				
Phonological				
Left	1,042 ± 41.05	0.03 ± 0.01	719 ± 29.12	0.06 ± 0.02
Right	1,051 ± 42.99	0.03 ± 0.01	730 ± 32.14	0.08 ± 0.02
Bilateral	1,053 ± 42.31	0.04 ± 0.01	721 ± 32.44	0.06 ± 0.02
Semantic				
Left	990 ± 26.30	0.02 ± 0.01	684 ± 17.59	0.03 ± 0.01
Right	992 ± 25.97	0.03 ± 0.01	689 ± 19.64	0.04 ± 0.01
Bilateral	1,006 ± 30.29	0.02 ± 0.01	686 ± 17.91	0.04 ± 0.01
Perceptual				
Left	1,060 ± 25.15	0.09 ± 0.02	645 ± 14.48	0.12 ± 0.02
Right	1,052 ± 23.48	0.11 ± 0.02	637 ± 13.61	0.12 ± 0.02
Bilateral	1,053 ± 25.40	0.10 ± 0.03	645 ± 14.32	0.14 ± 0.02

ER, error rates in percentage of trials; RTs, reaction times in ms.