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# Right-hemisphere motor facilitation by self-descriptive personality-trait words

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## Abstract

The emergent picture from the literature on the processing of self-related information suggests that in addition to the neural mechanisms involved in recognizing one's own face, there may also be neural representations of the self that are modality independent and favour the right hemisphere. We used focal, single-pulse transcranial magnetic stimulation in human subjects to assess cortical excitability during covert reading of self-descriptive personality-trait words. We hypothesized that the right hemisphere would show a greater overall facilitation to personality-trait words than the left hemisphere. Overall, personality-trait words led to significantly greater motor facilitation in the right hemisphere than in the left hemisphere. In addition, words rated as 'never' self-characteristic yielded significant right hemisphere facilitation, and words rated as 'always' self-characteristic showed a similar trend. The results are discussed in terms of the notion that the right hemisphere plays a dominant role in both self-relevant processing and the processing of affective stimuli.

## Introduction

Previous studies have demonstrated a special contribution of the right hemisphere (RH) in self-related cognition (Stuss & Benson, 1986; Decety & Chaminade, 2003; Platek *et al*., 2004a), own-body perception (Brugger *et al*., 1997; Blanke *et al*., 2002; Blanke & Arzy, 2004), self-awareness (Stuss, 1991; Andelman *et al*., 2004; Barnacz *et al*., 2004), autobiographical memory (Stuss & Benson, 1986; Fink *et al*., 1996; Levine *et al*., 1998; Lou *et al*., 2004) and theory of mind (Baron-Cohen *et al*., 1994; Stone *et al*., 1998; Platek *et al*., 2004a). Many studies of self-face recognition have also found an RH advantage (Keenan *et al*., 1999, 2000b, 2001, 2003; Sugiura *et al*., 2000, 2004; Platek *et al*., 2004a; Uddin *et al*., 2004), suggesting a special role for the RH in processing material related to the self (Keenan *et al*., 2000a). In addition to the neural mechanisms involved in recognizing one's own face, there may also be neural representations of the self that are modality independent and favor the RH (Craik *et al*., 1999; Keenan *et al*., 2000a; Fossati *et al*., 2004; Platek *et al*., 2004b).

Functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) studies on the retrieval of personality-trait words implicate a neural network comprising midline structures (medial prefrontal cortex, anterior and posterior cingulate regions and the precuneus) interacting with more lateral regions (left temporal cortex and right inferior parietal cortex) (Kelley *et al*., 2002; Fossati *et al*., 2003; Lou *et al*., 2004; Macrae *et al*., 2004). Among these regions, activity in the medial prefrontal cortex (MPFC) predicts whether individuals find a trait to be self-descriptive (Macrae *et al*., 2004). Unlike self-face recognition, which recruits specific visual processing, or autobiographical representation, which invokes memory retrieval processes (Fink *et al*., 1996; Keenan *et al*., 2001), personality-trait words likely access a representation of the self predominantly through linguistic processing.

Platek *et al*. (2003) reported on the laterality of processing of self-descriptive adjectives in high and low schizotypal subjects. They found that low schizotypal subjects responded faster with their left hand (controlled by the RH) to adjectives that were self-descriptive. Those scoring high on the Schizotypal Personality Questionnaire (Raine, 1991) did not show this left hand advantage. The authors interpreted this result as converging evidence that the RH is involved in processing information about the self in neurologically healthy subjects (Platek *et al*., 2003). Thus, converging evidence from neuroimaging and behavioral studies indicates that there is a representation of the self that can be accessed through the linguistic modality, and this representation or access to it may invoke processing by the RH.

Transcranial magnetic stimulation (TMS) is becoming increasingly widely used as a tool for cognitive studies (Pascual-Leone *et al*., 2000; Bailey *et al*., 2001). TMS has been used to investigate the lateralization of self- and non-self-action observation (Patuzzo *et al*., 2003), self-induced sadness and happiness (Tormos *et al*., 1997) and self-face recognition (Keenan *et al*., 2000a, 2001; Theoret *et al*., 2004). Of particular interest is a recent study showing a relative increase in corticospinal excitability of the RH when subjects viewed masked pictures of their own face, indicating that even without explicit awareness, self-relevant stimuli modulate corticospinal excitability

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(Theoret *et al*., 2004). TMS has also been used to show that both productive and receptive linguistic tasks excite the motor cortical representation of the hand in both hemispheres, pointing toward a direct link between language and the motor system (Floel *et al*., 2003). Modulation of TMS-induced motor-evoked potentials (MEPs) by such diverse cognitive functions is thought to reflect general hemispheric activation (Tormos *et al*., 1997; Keenan *et al*., 2001; Theoret *et al*., 2004). Thus, TMS can be used successfully to assess general hemispheric cortical excitability for self-related stimuli in the motor, emotional and visual domains, and its effects can also be modulated by linguistic input.

To investigate a representation of the self, accessed through the linguistic modality, we measured the excitability of the hand representation of the motor cortex using TMS while subjects were covertly reading self-descriptive personality-trait words. Although it is commonly accepted that language is a predominantly left-lateralized process (Knecht *et al*., 2000; Josse & Tzourio-Mazoyer, 2004), we predicted that the RH would be significantly more facilitated by self-descriptive personality-trait words than the LH. In addition, we predicted that words rated as 'always' self-descriptive would lead to the greatest motor facilitation, words judged as 'never' self-descriptive would lead to the least facilitation and words rated as 'sometimes' self-descriptive would be intermediate (always > sometimes > never). Activating or recruiting a representation through any of these words would lead to an overall increase in the excitability of the right cortical hemisphere as measured by MEPs recorded from the contralateral hand.

## Methods

Thirteen subjects (seven males) were recruited for this study, which was approved by the UCLA Institutional Review Board, and conformed to The Code of Ethics of the World Medical Association (Declaration of Helsinki). Written informed consent was obtained from all subjects. All subjects were right-handed according to a modified Edinburgh Handedness Questionnaire (Oldfield, 1971). The subjects were screened for neurological, psychiatric and medical problems, drug use, as well as contraindications to TMS (Wassermann, 1998). Participants' mood was assessed using the Beck Depression Inventory (Beck *et al*., 1961) to ensure that our measure of motor excitability of each hemisphere was not affected by depressive hemispheric activity (Shenal *et al*., 2003; Rotenberg, 2004). Five subjects (three males and two females) were excluded from the study owing to: (a) the inability to collect reliable MEPs from both hemispheres (two subjects) and (b) the fact that the accurate peak-to-peak amplitudes of MEPs could not be measured because the MEP often saturated at the gain used in some sessions (three subjects). The remaining eight subjects (four males) had a mean age of 26.25 years (range 20–38 years). Their mean Beck Depression Inventory score of 4.5 (SD = 4.78) was well within the lowest range (0–13) clinically associated with minimal depression. Additionally, a recent study found no consistent relationship between motor cortical excitability and laterality in depression (Fitzgerald *et al*., 2004).

As stimuli, we randomly chose 250 words from Anderson's Likableness Rating list (i.e. stingy, stubborn, productive, talented) (Anderson, 1968). The frequency distribution of our 250 chosen personality-trait words reflects the overall characteristics of the frequency distribution of the original list. We found that there is a relative lack of neutral words and roughly equal frequency of 'favorable' and 'unfavorable' words, with a slight prevalence of 'unfavorable' words (Anderson, 1968). For baseline stimuli, we chose 50 additional adjectives that are not normally used to describe personality (i.e. aerial, illegal, cavernous, clammy). From this randomized list of 300 words, subjects rated how well each adjective described themselves on a ten-point scale ('1' never characteristic of me; '10' always characteristic of me). They also had the option to choose a column marked 'irrelevant'. Subject's own-personality-trait ratings were obtained 20 min prior to TMS data collection. From subjects' ratings, we chose ten personality-trait adjectives rated as 'always' (score 8–10), ten rated as 'sometimes' (score 5–6) and ten rated as 'never' (score 1–3) characteristic of the self. For the baseline condition, we chose ten of the words rated as 'irrelevant', which for all subjects were part of the 50 adjectives not normally used to describe personality. For each category, we chose the ten words with the highest rating assigned by the subject as belonging to that particular category for use as stimuli. Thus, stimuli were individually tailored to each participant. Because it was essential to use personalized stimuli in this self-referential experiment, it was not possible to match the stimuli on such linguistic parameters as frequency, as this would depend on the specific words chosen by each individual.

Subjects were seated in front of a computer monitor, with their head in a chin rest and fitted with a neck brace to minimize head movement. Focal TMS was delivered through a 90-mm angled figure-of-eight coil using a High Speed MES-10 stimulator (Cadwell Laboratories, Inc.) over the right or left primary motor cortex. MEPs were recorded from the first dorsal interosseous (FDI) muscle of each hand. The coil was held tangentially on the scalp, approximately perpendicular to the central sulcus, 45° from the anterior–posterior axis, with the handle pointing posteriorly over the optimal spot for eliciting MEPs in the contralateral FDI muscle (Brasil-Neto *et al*., 1992) (amplification ×1000–5000, band-pass filter 0.3–1000 Hz, digitization sampling rate of 2 kHz/channel). MEPs were recorded using 10-mm Ag/AgCl surface electrodes with the active electrode placed over the motor point and the reference electrode placed over the tendon of the muscle.

The resting motor threshold (MT) was assessed according to conventional criteria, i.e. the minimal stimulator output that induced MEPs of at least 50 μV in five out of ten trials (Rossini *et al*., 1994), and determined separately for each hemisphere. Output of the stimulator was subsequently adjusted to 20% above resting MT to produce an MEP with peak-to-peak amplitude of at least 50 μV during the experimental conditions. Background electromyogram (EMG) activity was monitored to ensure that subjects maintained relaxed hand muscles during all tasks.

To assess hemispheric differences in the change of the size of the MEP during the experimental tasks, each subject was stimulated over the left and right hemispheres. The order of stimulation sites was counterbalanced between subjects. For each hemisphere, 40 trials were recorded: ten for the baseline condition, ten for the 'never' condition, ten for the 'sometimes' condition and ten for the 'always' condition. The words were centrally presented for 1 s, and the TMS pulse was delivered 750 ms after stimulus onset. Each stimulus was followed by 5 s of rest. The order of stimuli was fully randomized across subjects using an online research randomizer (http://www.randomizer.org/). Subjects were instructed to read the words silently. A visual representation of a trial is shown in Fig. 1.

Peak-to-peak amplitudes of the MEPs were averaged, and mean amplitudes obtained during experimental conditions ('always', 'sometimes', 'never') were normalized to the mean MEP obtained during reading of the 'irrelevant', non-self-referential adjectives (baseline condition). For each subject, the mean MEP size for each experimental condition was divided by the mean MEP size for the baseline condition, multiplied by 100 and subtracted from 100 to give the percentage change from baseline (Tormos *et al*., 1997; Topper *et al*., 1998; Sundara *et al*., 2001; Aziz-Zadeh *et al*., 2004b). MEPs ± 2SD

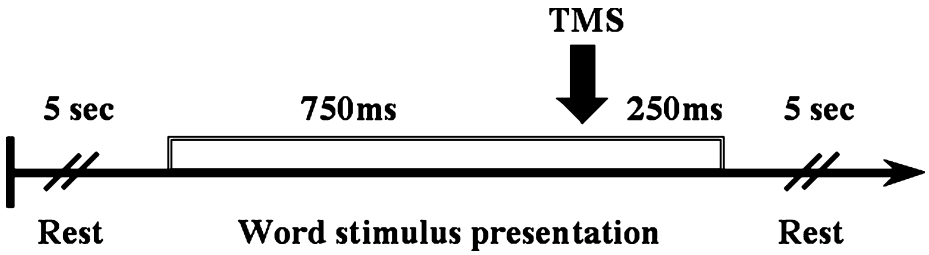


FIG. 1. Sample experimental trial. Visual illustration of one trial of the experiment. In each subject, for each hemisphere, 40 trials were recorded: ten for the baseline condition, ten for the 'never' condition, ten for the 'sometimes' condition and ten for the 'always' condition. The words were centrally presented for 1 s, and the TMS pulse was delivered 750 ms after stimulus onset. Each stimulus was followed by 5 s of rest.

away from the mean of each subject's data were excluded from the analysis. Fewer than one out of 40 MEPs recorded from each hand of a subject were excluded on this basis. Relative amplitudes were calculated indicating the change in cortical excitability in response to self-descriptive personality-trait words compared with a baseline of adjectives judged to be self-irrelevant. We use the term self-descriptive to describe all three self-characteristic stimulus conditions ('always', 'sometimes', 'never') throughout the discussion of our results. Owing to the nature of the task, it is difficult to choose a descriptive term to encompass the full meaning and relevance of our stimuli. Within self-descriptive stimuli, where necessary, we specify a particular condition by name.

## Results

The effect of self-descriptive personality-trait words on corticospinal excitability was evaluated using a two-way repeated-measures analysis of variance (ANOVA), with hemisphere (LH, RH) and self-relevance ('never', 'sometimes', 'always') as factors. Based on previous research using MEPs as a measure of general excitability of the cortical hemispheres to study self-related information processing (Keenan *et al.*, 2001; Theoret *et al.*, 2004) we predicted an RH facilitation by self-descriptive personality-trait words. As predicted, we found a significant main effect of hemisphere ($F_{1,7} = 3.61$, $P$(one-tailed) $< 0.05$). The significantly greater facilitation in the RH than in the LH during the silent reading of self-descriptive personality-trait words is shown in Fig. 2.

To test the hypothesis that among the self-descriptive word categories the 'always' words would show the greatest facilitation, and the 'never' words would show the least facilitation, we performed paired *t*-tests on the normalized MEP data for all three self-descriptive categories ('never', 'sometimes', 'always') separately. As shown in Fig. 3, the 'always' words showed a trend toward significantly more facilitation in the RH than in the LH ($P = 0.08$). Surprisingly, the 'never' words showed significantly stronger facilitation in the RH than in the LH ($P < 0.05$). The laterality difference for the 'sometimes' words was not significant.

To look at the word category effect within each hemisphere, we performed paired *t*-tests on the normalized MEP data comparing each of the self-descriptive word categories against all the others ('always' – 'never', 'sometimes' – 'always' and 'sometimes' – 'never') within both the LH and the RH. None of these comparisons was significant ($P > 0.05$).

We quantified the total number of words chosen by each subject within each category of the stimulus set – 'always', 'sometimes', 'never' and 'irrelevant'. These results are presented in Table 1. We also compared the likableness scores (Anderson, 1968) of the words chosen by the subjects and used as stimuli in the experiment. In

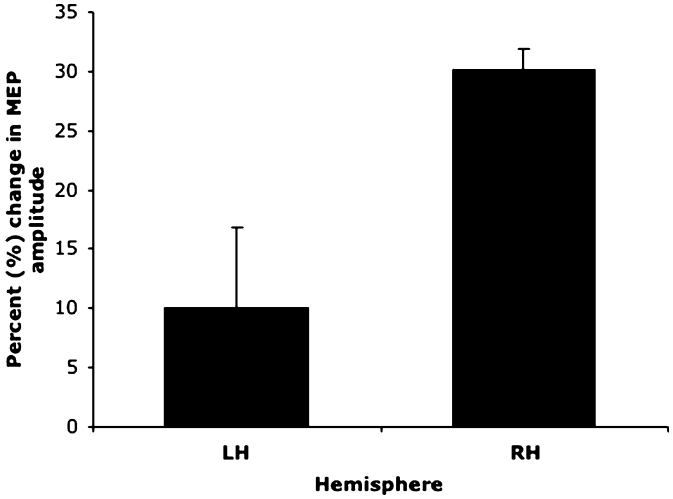


FIG. 2. Effect of hemisphere. Overall percentage change (± SEM) in MEP amplitudes in the left (LH) and right (RH) hemispheres during silent reading of all self-descriptive personality-trait words normalized to reading non-personality-trait adjectives ($P < 0.05$).


FIG. 3. Effect of word type. Percentage change (± SEM) in MEP amplitudes in the left (grey bars) and right (black bars) hemispheres during silent reading of self-descriptive personality-trait words rated as 'never', 'sometimes' or 'always' self-characteristic. All responses normalized to silent reading of non-personality-trait adjectives. The 'always' words showed a trend toward significantly more facilitation in the RH than the LH and the 'never' words showed significantly stronger facilitation in the RH than in the LH ($P < 0.05$).

TABLE 1. Subjects' word-type ratings.

| | Number of words 'characteristic of me' (and ratings) | | | |
|---|---|---|---|---|
| | Never | Sometimes | Always | Irrelevant |
| (Ratings) | (1–3) | (5–6) | (8–10) | – |
| Subject | | | | |
| S01 | 31 | 102 | 21 | 34 |
| S03 | 67 | 85 | 64 | 19 |
| S07 | 70 | 79 | 65 | 17 |
| S08 | 85 | 73 | 33 | 48 |
| S09 | 68 | 59 | 57 | 37 |
| S10 | 73 | 71 | 52 | 46 |
| S11 | 55 | 70 | 58 | 48 |
| S12 | 117 | 50 | 101 | 18 |

Total number of words from a list of 300 rated by each subject on a 1–10 self-characteristic scale. The list includes 250 adjectives from Anderson's Likableness Rating list (Anderson, 1968) and 50 control adjectives not generally used to describe personality. On the scale, 1–3 correspond to 'never characteristic of me', 5–6 are words rated as 'sometimes characteristic of me' and 8–10 ratings correspond to words rated as 'always characteristic of me'. The words thought to be not self-descriptive were rated as 'irrelevant'.

planned comparisons across the three self-descriptive categories ('always', 'sometimes', 'never'), we found no difference in the likableness rating of the words presented during stimulation of the LH and the RH ($P > 0.05$). In addition, the words did not differ in likableness between hemispheres within any of the three individual categories. However, across categories, words rated as 'never' self-characteristic had significantly lower likableness ratings than words rated as 'sometimes' self-characteristic ($P < 0.05$), which in turn had significantly lower likableness ratings than words rated as 'always' self-characteristic ($P < 0.05$).

## Discussion

We used TMS to measure cortical excitability in the left and right hemispheres during reading of self-descriptive personality-trait words. We found that the RH was significantly more facilitated by the reading of self-descriptive words than the LH. In addition, the RH was also significantly more facilitated than the LH by words that were chosen by subjects as 'never' characteristic of themselves, and those chosen as 'always' self-characteristic showed a similar trend. Our data add to the growing body of evidence that there are hemispheric differences in the processing of self-related stimuli.

The task used in this study, silent reading of previously rated personality-trait adjectives as self-descriptive or not self-descriptive, contains cognitive components related to both LH linguistic processing and RH affective processing (Borod *et al*., 1998; Faust *et al*., 2004). Although several studies using TMS have shown that increased excitability of the cortex owing to linguistic processing is reflected in the MEP of the hand motor representation, some investigated only the LH (Fadiga *et al*., 2002; Oliveri *et al*., 2004), one found no reliable effect of silent reading in either hemisphere (Tokimura *et al*., 1996) and some showed facilitation in the dominant (left) hemisphere only during reading aloud (Tokimura *et al*., 1996; Meister *et al*., 2003). One study using TMS found bilateral facilitation for both productive and receptive language tasks (Floel *et al*., 2003). Bilateral activation has also been observed in functional imaging studies using various language tasks (Dapretto & Bookheimer, 1999; Kircher *et al*., 2001; Crottaz-Herbette *et al*., 2004), but linguistic processing generally leads to a preponderance of left hemisphere activity (Neville *et al*., 1998; Capek *et al*., 2004). Our current finding that reading self-descriptive personality-trait words elicits greater MEPs from the RH is unique, and likely means that the facilitation we observe is not due only to processing of the self-descriptive personality-trait words as linguistic stimuli, but is modulated by the meaning of the adjectives.

The emotional valence of our stimuli may be one dimension that influenced the lateralized facilitation we observed. Some neuroimaging studies have supported the traditional notion that positive emotions are lateralized to the LH, and negative emotions to the RH (Tucker *et al*., 1981; Davidson & Fox, 1982; Baxter *et al*., 1989; Canli *et al*., 1998). On the other hand, others have suggested that there is both a bilateral and a lateralized component to the processing of emotional stimuli (Davidson & Irwin, 1999; Buchanan *et al*., 2000) and a recent meta-analysis of 65 neuroimaging studies of emotion found only limited support for a valence-related lateralization of emotion (Wager *et al*., 2003).

Results from studies of self-related emotional stimuli have also been mixed. TMS was used to show a facilitation of MEPs by stimulation of the LH during self-induced sadness, while happy thoughts induced a facilitation in the RH (Tormos *et al*., 1997). An fMRI study using self-descriptive positive and negative words found processing related to the self recruited the right dorsomedial prefrontal cortex, regardless of the valence of the words (Fossati *et al*., 2003). A subsequent study by the same group found greater activations in the RH for negative self-related traits and also for self-positive words compared with self-negative words (Fossati *et al*., 2004). These latter findings are inline with our results showing an overall RH facilitation for self-descriptive personality-trait words, including both the most likable and the least likable adjectives. This may suggest that valence of the self-descriptive adjectives is not what gives rise to the facilitation we see in the RH, and this facilitation may be driven by a true self-relevance effect.

To assess the emotional valence of our stimuli, we compared the likableness ratings (Anderson, 1968) of the words used in the experiment, and found them to be significantly different across the three self-descriptive categories. Our results show that words that subjects rated as 'never' characteristic of the self are perceived as significantly less likable than words rated as 'sometimes' characteristic. Words rated as 'always' characteristic of the self are perceived as significantly more likable than words rated as 'sometimes' characteristic. Our data show a significant RH facilitation for the least likable words ('never' like self) and a similar trend for the most likable words ('always' like self). This suggests that our result of RH facilitation to self-descriptive words more likely reflects a self-relevance effect than a valence effect, as both most likable and least likable rated stimuli lead to increased MEPs in the RH. If the facilitation we observed had been driven solely by the affective valence of the stimuli, we may have expected a lateralized response to positive and negative words as predicted by the valence hypothesis (Sackeim *et al*., 1982; Davidson, 1992; Gur *et al*., 1994; Canli *et al*., 1998).

The processes by which personality traits may be attributed to the self in our paradigm can be thought of as verbal self-description or affective self-description. If one believes that verbal self-description prevails in this task, LH dominance would be expected, as this mode of attribution relies on linguistic processes to define the characteristics of the self (Faust *et al*., 2004). On the other hand, if an affective process is used to characterize the self, one would expect it to recruit the RH (Fossati *et al*., 2004). In a test of this hypothesis, Faust *et al*. (2004) concluded in favor of the verbal account, but they also found RH advantage for personality-trait words that do not describe the self. We also found facilitation in the RH versus the LH for words rated as 'never' characteristic of the self. If this corticospinal facilitation

reflects activation or access to a self-representation in the RH, our result may indicate that traits rated as 'never' self-characteristic are also part of the self-schema.

Self-schemata are cognitive representations of the self, derived from past social interactions and experiences that promote elaboration and organization of stored information and may be used to guide behavior (Markus, 1977). As traits are incorporated into the self-schema, subsequent memory for these trait-words is increased (Rogers *et al*., 1977), a phenomenon labeled the Self Reference Effect (Symons & Johnson, 1997). At the neural level, this implies a reactivation during retrieval of the structures used during encoding. Neuroimaging studies have found a RH network to be involved in self-descriptive and autobiographical memory (Fink *et al*., 1996; Wheeler *et al*., 1997; Craik *et al*., 1999). Fossati *et al*. (2004) found that the correct recognition of self-related positive and negative words reactivated the right MPFC. Activity in this region was driven by the self-negative words, indicating that self-characteristic negative stimuli may facilitate retrieval of the self-schema (Fossati *et al*., 2004). Similarly, we found a significant RH facilitation for words perceived as most negative and rated as 'never' characteristic of the self. This finding may indicate that the self-schema as a cognitive structure incorporates both positive and negative personality traits. Furthermore, during self-related processing the self-schema may facilitate activation of self-descriptive traits for both words judged as 'always' and words judged as 'never' characteristic of the self.

The notion that one idea is triggered by the presence of a related object is known as the automatic activation of attitudes (Fazio *et al*., 1986). In terms of this experiment, such 'automatic activation' is implied when words with a clear antonym, such as 'tense–relaxed', 'generous–stingy' or 'honest–dishonest', are judged to belong to either the 'always' or the 'never' self-characteristic category. When one of the pair of words is presented, it may elicit the activation of its antonym, and an evaluation of its self-relevance. As both of the pair of self-descriptive personality traits is invoked, this effect may help explain our right lateralized facilitation of the MEP by traits judged as 'always' and 'never' characteristic of the self.

Furthermore, social desirability effects may have modulated the self-characteristic ratings of the stimuli (Leary *et al*., 2003). This implies that subjects may have rated words they know to be socially undesirable as 'never' self-characteristic in order to present a more positive self-image. Even if this was the case, our results show that the words judged as 'never' self-characteristic did activate the RH self-descriptive representations. Further studies are needed to understand better how each of these factors contributes to the development and organization of the self-concept.

An interesting pattern in our results is the symmetric facilitation of the corticospinal excitability in the left and right hemispheres by the words rated as 'sometimes' self-characteristic. It is likely that these words are more ambiguous to the subject in terms of both emotionality and self-relevance. Such ambiguity may lead to increased cognitive linguistic processing in the LH as well as increased recruitment of RH resources for processing self-relevance. Emotional ambiguity may draw on the resources of both hemispheres and the sum of this activity leads to the facilitation we observe for 'sometimes' words in both the LH and the RH. The fact that less ambiguous words were rated as either 'never' or 'always' self-characteristic may explain the right lateralized facilitation we observe for those words, and is consistent with the notion that an established self-schema is driving more automatic processing of these words in the RH.

In conclusion, our finding of a significant overall RH motor facilitation for personality-trait words is well supported by previous research suggesting that the RH plays a special role in processing self-descriptive information. In addition, our finding that both words judged to be least likable and most likable led to more facilitation in the RH than the LH may indicate that the self-schema is a cognitive construct defined by both positive and negative personality traits. Both these findings support a RH advantage in processing information about the self. We have also shown that TMS can be used successfully to assess excitability of the cortical hemispheres for higher-level cognitive tasks such as perception of self-descriptive personality-trait words.

## Interpretational limitations

This study has some limitations that must be considered in interpreting the findings. Our stimulus set was determined by personality-trait words rated by subjects on a scale of 'always' to 'never' self-characteristic. As discussed above, the words judged to be 'always', 'sometimes' and 'never' self-characteristic differed significantly in their likableness ratings. Words judged to be always self-characteristic were rated as being significantly more likable than words judged to be never characteristic of the self. As a result, the likableness of the words, which may be related to valence, is confounded with the degree to which subjects found the words to be self-characteristic or not.

Additionally, in comparing the words rated as 'always' and 'never' self-characteristic with the 'sometimes' words, we may be confounding two dimensions of the emotional experience, valence and arousal. Valence refers to the pleasant–unpleasant dimension of an emotion, while arousal refers to the intensity of that emotion. As the words differed significantly in their likableness ratings, it may be that they were also different in terms of arousal. As the 'sometimes' words were perhaps more ambiguous or even neutral emotionally, they may be less arousing than either the 'always' or 'never' words. Thus, the processing of these words is more weighted toward a linguistic versus an affective process, which may have led to a greater motor facilitation for these words in the LH.

Related to the linguistic interpretation of the stimuli, we also face the additional challenge that not all words rated as never self-characteristic are necessarily negative descriptors of the self. Rating a word as 'never' self-characteristic may simply mean that the subject believes that the word does not describe himself or herself, and as a result, the trait may not be represented in that individual's self-schema. A possible alternative to considering 'never' words as self-descriptive is perhaps to consider these, instead of the 'irrelevant' words, as baseline stimuli. Although this may be worth exploring, it does appear from our results that the 'never' words contribute an important dimension to the self-descriptive traits that form the self-schema. Indeed, some subjects did rate personality-trait words as 'irrelevant' when they felt that the trait was not self-relevant.

Finally, one must take into account that we only had eight subjects who had utilizable data in the experiment; however, other TMS studies have also used eight or fewer subjects to study cognitive phenomena (Heiser *et al*., 2003; Aziz-Zadeh *et al*., 2004a; Theoret *et al*., 2004).

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## Abbreviations

EMG, electromyogram; FDI, first dorsal interosseus; fMRI, functional magnetic resonance imaging; LH, left hemisphere; MEP, motor-evoked potential; MPFC, medial prefrontal cortex; MT, motor threshold; PET, positron emission tomography; RH, right hemisphere; TMS, transcranial magnetic stimulation.

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