



The relationship between semantic access and introspective awareness

Xu Xu^{a,*}, Chunyan Kang^b, David Pascucci^a, Taomei Guo^{b,c,*}

^a School of Foreign Languages, Shanghai Jiao Tong University, China

^b State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University, China

^c Center for Collaboration and Innovation in Brain and Learning Sciences, Beijing Normal University, China

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ABSTRACT

There have long been speculations about the relationship between consciousness and language. This study aimed to determine whether an individual's level of introspective awareness, based on self-report, relates to accessibility of their semantic system as evaluated by the N400. Thirty-five university students completed the study. All were right-handed, with normal or corrected-to-normal vision, without known neurological or psychological health issues. They first performed on a lexical decision task while their brain electrophysiological responses were recorded. Then, they provided assessment ratings about their levels of introspective awareness. Analysis revealed moderate to strong correlations (*Pearson's rs* = 0.49–0.62) between awareness self-ratings and ease of semantic access as indexed by the N400. Correlation between the self-report measure and the objective neurophysiological measure suggests that subjective assessment of awareness may deserve more credibility, which in addition to reflecting subjective perception and evaluation about one's own higher order mental functioning, may also interact with the neurophysiological processes contributive and subject to such awareness. Implications for future research on the role of semantic network in the mechanism of introspective awareness are discussed.

1. Introduction

Recent literature has indicated advancements in the search for neural correlates of perceptual awareness, i.e., awareness of visual, auditory, or haptic stimuli (e.g., de Graaf, Hsieh, & Sack, 2012; Fleming, Weil, Nagy, Dolan, & Rees, 2010; Pun, Emrich, Wilson, Stergiopoulos, & Ferber, 2012; Railo, Koivisto, & Revonsuo, 2011; Rees, 2007). For example, Fleming et al. (2010) showed that accuracy level of perceptual awareness was associated with individual differences in grey matter volume of areas within anterior prefrontal cortex and white matter microstructure connected to these areas. However, there has been limited neurophysiological research on awareness of non-perceptual events, i.e., awareness of one's own thoughts or feelings. That is, although researchers have achieved better understanding about the neural substrates serving awareness of external stimuli, much remains to be learned about the neural mechanism involved in awareness of our internal states. This has been the case despite the fact that our capability to self-monitor and to make valid and reliable assessment about our own higher-order mental functioning has long been a point of debate (e.g., Schellings & van Hout-Wolters, 2011; Schwartz & Metcalfe, 1994). Awareness of internal states such as memories and emotions constitutes an essential dimension of self-awareness; such introspective

awareness plays a vital role in our cognitive and social functioning (Duval & Wicklund, 1972; Fenigstein, Scheier, & Buss, 1975). The present study attempts to explore brain activities potentially related to this important aspect of self-awareness

Drawing upon current knowledge from research of semantic processing, this study examined introspective awareness in relation to semantic access. Specifically, through an extensive literature review of functional neuroimaging studies, Binder, Desai, Graves, and Conant (2009) identified a left-lateralized neural network of semantic processing, encompassing posterior inferior parietal lobe, middle temporal gyrus, fusiform and parahippocampal gyri, dorsomedial prefrontal cortex, inferior frontal gyrus, ventromedial prefrontal cortex, and posterior cingulate gyrus. They further pointed out that this semantic system was virtually identical to the neural network subserving autobiographical memory retrieval (Svoboda, McKinnon, & Levine, 2006). Binder et al. proposed the following explanations for the convergence of the two systems. First, autobiographical memories contain learned facts (i.e., semantic knowledge) about the self, which therefore should be supported by the same system for storage and processing of semantic knowledge. Second, autobiographical memories (e.g., *I played tennis last weekend.*) are constituted of concepts (e.g., *tennis, play, and weekend*), and thus retrieval of autobiographical memories necessarily entails

* Corresponding authors at: School of Foreign Languages, Shanghai Jiao Tong University, 800 Dongchuan Rd., Shanghai 200240, China (X. Xu). State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University, 19 Xijiekouwai St., Beijing 100875, China (T. Guo).

E-mail addresses: xu.xu@sjtu.edu.cn (X. Xu), guotm@bnu.edu.cn (T. Guo).

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retrieval of semantic knowledge (Binder et al., 2009). Based on these premises, the semantic system must be implicated in the mechanism of introspective awareness. Specifically, as an important part of autobiographical memory, representations of introspective experiences, e.g., *forming of a belief, an act of reasoning, or a prolonged emotional state*, would require a full support from the semantic system. Rich introspective experiences therefore may be associated with well-structured and readily accessible semantic knowledge.

There have long been speculations about the relationship between conscious awareness of subjective experiences and the use of language. Rosenthal (2005) argued that we gain conscious access to our cognitive and affective processes when we can attach a label or form a verbal narrative about what is taking place in the mind. Although there has been little empirical research to evaluate such argument, recent research appears to have offered indirect evidence pointing to a role of the semantic network in introspective awareness. For example, Binder et al. (2009) discussed the structural and functional similarities of the semantic network to the default mode network (DMN, Raichle, MacLeod, Snyder, Powers, Gusnard & Shulman, 2001). The latter refers to areas including medial prefrontal cortex, the temporoparietal junction, medial and lateral temporal lobes, posterior cingulate cortex, and lateral parietal lobes. These areas show high levels of spontaneous, ongoing neural activities during relaxed or resting state, which are commonly engaged in metacognitive processes such as prospection, retrospection, and theory of mind reasoning (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Schooler et al., 2011; Spreng & Grady, 2009). The DMN has been a focus of neural imaging studies about disorders of consciousness and about self-referential and emotional processing. These studies appear to suggest that an intact DMN is essential to emergence of conscious awareness (e.g., Boly et al., 2009; Soddu et al., 2011) and that the DMN is involved in retrieval and evaluation of introspective experience (e.g., Gusnard, Akbudak, Shulman, & Raichle, 2001; Whitfield-Gabrieli et al., 2010).

The present study directly examined the relationship between level of introspective awareness, assessed fittingly by self-report, and accessibility of the semantic network, indexed by the N400, an ERP component representing activation of semantic knowledge. The N400 elicited by a word stimulus can be seen roughly between 200 and 500 ms post word onset, most evident over central and parietal areas. It represents the process of meaning construction through accessing associated semantic knowledge (Kutas & Federmeier, 2000). More importantly, individuals vary in their baseline levels of N400, reflecting individual differences in ease of semantic access (Kutas & Federmeier, 2011; van Berkum, 2009). A correlation between the self-report and the N400 measures would indicate an association between level of introspective awareness and accessibility of the semantic system, which may offer insight to future research on the neural mechanism of introspective awareness. Furthermore, such research may have clinical implications. For example, patients with schizophrenia and depression often show disturbances in awareness of their internal states (Hamilton et al., 2012; Nelson, Whitford, Lavoie, & Sass, 2014). A better understanding of introspective awareness in the healthy brain thus might contribute to advancing diagnostic and treatment strategies.

1.1. Study overview

In this study, participants responded to self-descriptive statements such as *I am usually aware of my thoughts* and *I'm often confused about the way that I really feel about things* (The Self-Reflection and Insight Scale; Grant, Franklin, & Langford, 2002). The scale was developed based on the theoretical framework about introspective aspect of self-awareness (Fenigstein et al., 1975). It evaluates the degree to which an individual is clearly aware of their own internal states such as thoughts and feelings. In addition, using a lexical decision task, we recorded participants' brain electrophysiological responses during semantic processing in order to assess individual differences in accessibility of their

semantic knowledge.

1.1.1. Two verb categories

Word stimuli of the lexical decision task included two verb categories representing different conceptual domains: mental verbs referring to mental activities (e.g., *doubt, reason, and plan*) and physical verbs referring to physical movements (e.g., *jump, throw, and squat*). These two types of concepts were chosen in order to determine whether, as hypothesized, greater introspective awareness is associated with a well-structured and readily accessible semantic system, rather than simply a reflection of extensive knowledge in a particular conceptual domain, i.e., knowledge about mental activities such as *reasoning* and *doubting* denoted by mental verbs. Specifically, should introspective awareness relate to ease of semantic access, participants' awareness self-ratings would be associated with the N400 elicited by both categories of verbs. Alternatively, if an association is found only for awareness self-ratings and the N400 elicited by mental verbs, it would not be convincing evidence to conclude that introspective awareness relates to semantic access. Instead, it only indicates that rich introspective experiences can be assessed through both types of measures: self-report and the N400 elicited by words that denote such experiences.

1.1.2. Potential sex differences

Sex differences, though often overlooked, have become increasingly evident in the neuroscience literature (Cahill, 2006). More importantly, research has revealed distinct sex-related differences in the neural mechanism of semantic processing. For example, Daltrozzo, Wioland, and Kotchoubey (2007) found that women showed earlier electrophysiological responses to verbal materials than did men, signaling more automatic processing possibly due to a well-structured semantic network. Further, Wirth et al. (2007) showed that, compared to men, women tended to engage in a deeper level of semantic processing, as evidenced by automatic integration of verbal information.

Moreover, directly relevant to the present study, ERP research on semantic processing indicated greater left hemisphere activities among men, but more balanced hemispheric activities among women (e.g., Jaušovec & Jaušovec, 2009; Nowicka & Fersten, 2001). For example, Nowicka and Fersten (2001) employed a half visual field paradigm to present verbal stimuli, and then compared latencies of interhemispheric transmission for men versus women. For women, the left-to-right and the right-to-left interhemispheric transmissions were similarly swift. In contrast, for men, the latency for right-to-left interhemispheric transmission was comparable to that of women, whereas the left-to-right interhemispheric transmission was significantly delayed, indicating left hemisphere dominance of the male brain in semantic processing. Neuroimaging research offered converging evidence. In a PET study, Jaeger et al. (1998) reported that, despite similar levels of performance on a semantic task, patterns of cerebral blood flow indicated left-lateralized activations among men, but bilateral activations in perisylvian areas among women.

These findings about sex differences in semantic processing suggest that there may also be potential sex-specific topographical differences in the relationship between introspective awareness and semantic access. The present study therefore examined the two sex groups separately. Should introspective awareness relate to brain activities underlying semantic processing, the association of awareness self-ratings and the N400 would display a left hemisphere prominence among men, but not among women.

In summary, the analysis of this study focused on activities within the N400 time window. If the semantic system is integral to the mechanism of introspective awareness, as discussed earlier, a high level of awareness may be associated with highly structured and readily accessible semantic knowledge, and vice versa. Thus, higher awareness self-ratings would be linked to efficient semantic access, reflected as an attenuated N400. Inclusion of two different verb categories should

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