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Investigations of hemispheric specialization of self-voice recognition

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ABSTRACT

Three experiments investigated functional asymmetries related to self-recognition in the domain of voices. In Experiment 1, participants were asked to identify one of three presented voices (self, familiar or unknown) by responding with either the right or the left-hand. In Experiment 2, participants were presented with auditory morphs between the self-voice and a familiar voice and were asked to perform a forced-choice decision on speaker identity with either the left or the right-hand. In Experiment 3, participants were presented with continua of auditory morphs between self- or a familiar voice and a famous voice, and were asked to stop the presentation either when the voice became "more famous" or "more familiar/self". While these experiments did not reveal an overall hand difference for self-recognition, the last study, with improved design and controls, suggested a right-hemisphere advantage for self-compared to other-voice recognition, similar to that observed in the visual domain for self-faces.

Self-recognition (the ability to recognize oneself) has been proposed (Gallup, 1985) to be an accurate measure of the presence of a self-concept (representation of one's own identity) and of self-consciousness (the ability to become the object of one's own attention), abilities which may underlie such higher-order cognitive capacities as theory of mind and introspection (Gallup, 1982). Indeed, some authors have shown that self-recognition, which is only observed in human beings, chimpanzees, orang-utans, and possibly dolphins, requires a certain level of self-concept (Keenan, Gallup, & Falk, 2003a). In terms of intellectual development, self-recognition appears at a stage (18–24 months) where other self-related behaviours are observed, and self-recognition itself has been used as a variable that successfully predicts the capacity for other self-related abilities such as self-conscious emotions (see Keenan et al., 2003a for review). Further, in clinical populations where self-recognition performance is compromised, there is a correlative absence of other self-related abilities, such as the absence of a left-hand advantage when processing self-descriptive traits (Christiana, Malcolm, Johnson, & Keenan, submitted for publication; Platek & Gallup, 2002; Platek et al., 2003).

The idea that self-processing (processing of self-related information) is unique and distinct from other types of semantic processing is supported by several recent studies. For example, Paus et al. (1996) showed that the cerebral motor regions involved in speech production send a corollary discharge to regions of secondary auditory cortex, thereby modulating their activation in response to the self-voice. In the domain of face processing, Ninomiya, Onitsuka, Chen, Sato, & Tashiro (1998) have reported a larger amplitude of the P300 brain wave when participants were presented with their own face compared to a familiar face, suggesting a greater attentional response to the self. Sugiura et al. (2000) have shown that the electrodermal response to the presentation of one's own face is greater than when participants were presented with a familiar face, suggesting a more important emotional response to self-related stimuli. Finally, several studies have demonstrated a mnemonic advantage for information processed in a self-referential manner (see Symons & Johnson, 1997). The above evidence suggests that self-related information processing is, if not unique, at least partially distinct from other types of processing. It should be noted, however, that although there is a growing body of work suggesting unique neural processing of self-related information, this claim is still somewhat controversial (see Gillihan & Farah, 2005).

The cerebral underpinnings of self-recognition are still a matter of investigation, but there is accumulating evidence suggesting that a lateralized network may be involved. However, the degree and even the nature of such lateralization remain unclear. A series of studies by Keenan and colleagues (Keenan, Freund, Hamilton, Ganis, & Pascual-Leone, 2000; Keenan et al., 1999; Keenan, McCutcheon, & Pascual-Leone, 2001a; Keenan, Nelson, O'Connor, & Pascual-Leone, 2001b; Keenan, Wheeler, Platek, Lardi, & Lassonde, 2003b) has shown that the right-hemisphere seems to be more involved in self-face perception. In a first study, participants were asked to identify either their own face, a familiar face or an unknown face (Keenan et al., 1999). Results showed that

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participants responded faster with their left-hand (right-hemisphere) than with their right-hand (left-hemisphere) when they where presented with upright or inverted self-faces, which is quite a large advantage as all participants were right-handed. In contrast, the presentation of upright or inverted familiar faces and unknown faces did not yield any advantage. Similarly, Platek & Gallup (2002) also found an advantage of the left-hand for the recognition of one's own face. In a second study by Keenan et al. (2000), participants were presented with movies in which one face transformed progressively into another through morphing. An advantage of the left-hand (right-hemisphere) for one's own face was also observed using this experimental paradigm. This right-hemisphere advantage for recognition of one's own face was subsequently replicated by the same group in studies using different paradigms in normal and brain-lesioned patients (electrophysiology, fMRI, Wada and TMS; Keenan et al., 2001a, 2001b, 2003b) and was confirmed by several other investigators in self-face recognition studies (e.g. Platek, Keenan, Gallup, & Mohamed, 2004a; Théoret et al., 2004; Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005). For example, in the study of Théoret et al. (2004), participants were presented with masked faces of oneself or of strangers while their left or right motor cortex was stimulated with TMS. Stronger motor evoked potentials were observed when participants were stimulated over the right motor cortex while viewing their own face, suggesting that the right-hemisphere was more activated. Moreover, imaging studies have generally found the right frontal and parietal regions to be involved in self-face recognition (e.g. Keenan et al., 2001a; Platek et al., 2004a; Uddin et al., 2005). Although there are but fewer studies indicating a left-hemisphere advantage (Brady, Campbell, & Flaherty, 2004; Turk et al., 2002), one should note that the finding of right-hemisphere dominance is not entirely consistent. Furthermore, all reports of patients with 'mirror-sign' (the exclusive loss of self-face recognition) showed right-hemisphere damage (Breen, Caine, & Coltheart, 2001; Feinberg & Shapiro, 1989; Spangenberg, Wagner, & Bachman, 1998), but only a handful of patients exhibit such a condition.

The human voice is one of the most important and most frequent sound categories in our environment. At the functional level, voices, as "auditory faces" (Belin, Fecteau, & Bédard, 2004), enable us to identify a person rapidly, efficiently and with ease. Voices contain within their physical structure a wealth of information (age, sex, and height, sociological and geographical background) on the identity and the emotional state of the speaker (Belin, Zatorre, & Ahad, 2002; Van Lancker & Canter, 1982). Hence, an important parallel can be made between the processing of voices and the processing of faces (Belin et al., 2004). For example, recognition of faces (Paller et al., 2003; Van Lancker & Canter, 1982; see also Benton, 1980 for a review) as well as processing (e.g. Belin et al., 2002; Belin, Zatorre, Lafaille, Ahad, & Pike, 2000; Nakamura et al., 2001) and recognition (e.g. Ellis, Young, & Critchley, 1989; Kapur et al., 1994; Van Lancker, Kreiman, & Cummings, 1989) of voices have both been shown to be more dependent upon the right-hemisphere. Thus, some authors (Van Lancker & Canter, 1982) have suggested that recognition of familiar voices, like recognition of familiar faces, require a global processing as accomplished by the right-hemisphere. Also, a specific impairment in processing and recognition of these two stimuli has been observed following cerebral lesions: prosopagnosia in the visual modality is the inability to recognize familiar faces (Gazzaniga, Ivry, & Mangun, 2001) and phonagnosia in the auditory modality is the inability to recognize and process familiar voices (Van Lanker, Cummings, Kreiman, & Dobkin, 1988). Finally, Van Lancker & Canter (1982) have pointed out that neonates show a marked preference for the voice and the face of their mother compared to other voices and faces.

Given the similarities between voice and face processing and the importance of one's own voice for self-recognition it seems surprising that only one published study has directly investigated the neural correlates of self-voice recognition (Nakamura et al., 2001). Using PET, Nakamura and his colleagues found more important right frontal activation when self-voices were compared to familiar-voices in a discrimination task between these familiar voices (familiar or self) and unknown voices. However, it remains unknown how such difference may relate to behavioural performance. It would thus be of significant interest to explore hemispheric specialization of self-voice processing and to verify if it concurs with a right hemispheric specialization for self-related stimuli.

The objective of the present set of studies is to determine the hemispheric specialization of self-voice recognition by essentially transposing to voices in the auditory modality the experiments performed by Keenan et al. (1999, 2000) on self-face recognition. In Experiment 1, participants were asked to identify one of three presented voices (self, familiar or unknown) by responding either with the right or the left-hand. In Experiment 2, participants were presented with auditory morphs between self and familiar voices, and were asked to indicate the most likely speaker either with the left or the right-hand. Finally, in Experiment 3, participants were presented with continua of morphs between a famous voice and either their own or a familiar voice and were asked to stop the presentation either when the voice became "more famous" or "more familiar/self". On account of the literature suggesting a right hemispheric specialization for self-face processing and for voice recognition, we hypothesized that the right-hemisphere would also be more involved in the recognition of one's own voice compared to other voices. Thus, in all the experiments, we predicted a stronger left-hand advantage, in terms of speed, accuracy and response bias, for self-voice recognition compared to other voices.

1. Experiment 1

1.1. Materials and methods

1.1.1. Participants

Fourteen right-handed French-Canadian normal participants (2 males and 12 females) between the ages of 21 and 26 (mean age = 23.5; *SD* = 1.3) were recruited at the University of Montreal through billboard postings. Participants consisted of pairs of friends or co-workers having known each other for at least one year. All participants in a pair were of the same sex and comparable age (<5 years apart). Each participant was also the familiar voice for his/her friend or co-worker. They received a compensation of 10 dollars per hour of testing for their participation. This study was approved by the University of Montreal's ethics committee. Participants signed a consent form prior to their participation in the study and their handedness was established using the Edinburgh Handedness Inventory (Oldfield, 1971). Auditory capacities of the participants were evaluated using a questionnaire and those with self-reported auditory difficulties were excluded from this study. Most of the participants underwent the three experiments that are presented here. The order of participation to each experiment was counterbalanced, thus minimizing biases related to order of experiments, such as priming.

1.1.2. Material

Vocal stimuli were generated based on 17 words (see Annex 1) pronounced by the participant, the familiar person or an unknown speaker. For the unknown speaker, two voices, one male and one female, were selected among the Vocal Neurocognition Laboratory natural voice bank. These voices were gender- and age-matched to the participants and there was no identifiable accent. As for the participant and the familiar speaker, their voices were recorded