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Paying attention to my voice or yours: An ERP study with words

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ABSTRACT

Self-related stimuli—such as one's own face or name—seem to be processed differently from non-self stimuli and to involve greater attentional resources, as indexed by larger amplitude of the P3 event-related potential (ERP) component. Nonetheless, the differential processing of self-related vs. non-self information using voice stimuli is still poorly understood. The present study investigated the electrophysiological correlates of processing self-generated vs. non-self voice stimuli, when they are in the focus of attention.

ERP data were recorded from twenty right-handed healthy males during an oddball task comprising pre-recorded self-generated (SGV) and non-self (NSV) voice stimuli. Both voices were used as standard and deviant stimuli in distinct experimental blocks. SGV was found to elicit more negative N2 and more positive P3 in comparison with NSV. No association was found between ERP data and voice acoustic properties.

These findings demonstrated an earlier and later attentional bias to self-generated relative to non-self voice stimuli. They suggest that one's own voice representation may have a greater affective salience than an unfamiliar voice, confirming the modulatory role of salience on P3.
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1. Introduction

Self-recognition represents the capacity to identify the physical and psychological aspects of ourselves, such as one's own voice, face or autobiographical memories (Gallup, 1985; Gallup et al., 2014; Gillihan & Farah, 2005). This ability emerges early in human development, around 18–24 months of age (Keenan, Gallup, & Falk, 2003; Nielsen, Dissanayake, & Kashima, 2003), and is thought to play a pivotal role in self-awareness and in a sense of agency (Gallup, 1985; Gallup et al., 2014; Jeannerod, 2003; Keenan et al., 2003; Platek et al., 2008). Impairments in this ability have been observed in some neuropsychiatric and neurodevelopmental disorders, such as schizophrenia (Waters & Badcock, 2010; Waters et al., 2012) and autism (Cygan, Tacikowski, Ostaszewski, Chojnicka, & Nowicka, 2014; Kita et al., 2011).

In the last decades, studies have suggested that self-related stimuli—such as one's own voice or face—are processed differently from non-self stimuli, involving behavioral and neural correlates that are distinct from those engaged in the processing of stimuli not related to the self. For example, behavioral studies show that in comparison with familiar and unfamiliar stimuli, one's own face is more rapidly identified (Keenan, Freund, Hamilton, Ganis, & Pascual-Leone, 2000; Sui, Zhu, & Han, 2006; Tacikowski & Nowicka, 2010; Tong & Nakayama, 1999). Furthermore, self-related stimuli such as one's own face or name elicit greater attentional resources than non-self stimuli (Chen et al., 2008; Eichenlaub, Ruby, & Morlet, 2012; Gray, Ambady, Lowenthal, & Deldin, 2004; Miyakoshi, Nomura, & Ohira, 2007; Perrin et al., 2005; Scott et al., 2005; Sugiura et al., 2000; Folmer & Yingling, 1997; Tacikowski & Nowicka, 2010), even when they are task-irrelevant (Berlad & Pratt, 1995; Gray et al., 2004; Holeckova et al., 2006; Müller & Kutas, 1996; Ninomiya et al., 1998; Perrin et al., 1999; Scott et al., 2005; Sui et al., 2006; Tateuchi, Itoh, & Nakada, 2012).

Event-related potential (ERP) studies have demonstrated important attentional biases to self-specific stimuli, as reflected by increased N2 (Fan et al., 2011; Fan et al., 2013; Perrin et al., 1999) and P3[1] amplitudes (Berlad & Pratt, 1995; Cygan et al., 2014;

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[1] Previous studies showed that the P3 component is not a unitary brain potential, and that it consists of, at least, two subcomponents that reflect distinct neural processes—the P3a and the P3b (see Polich, 2007). The P3a indexes an involuntary attentional switch elicited by an unpredictable task-irrelevant change in a regular aspect of the environment, whereas the P3b is believed to reflect the allocation of higher-order attentional resources to a task-relevant deviant event. Here, the term "P3" was consistently used throughout the manuscript to refer to the component

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Eichenlaub et al., 2012; Fan et al., 2013; Folmer & Yingling, 1997; Gray et al., 2004; Müller & Kutas, 1996; Miyakoshi et al., 2007; Perrin et al., 1999; Scott et al., 2005; Su et al., 2010; Sui et al., 2006; Tacikowski & Nowicka, 2010; Tacikowski et al., 2011, 2014; Zhao, Wu, Zimmer, & Fu, 2011) for self- compared with non-self stimuli (see Appendix A in Supplementary material for a summarized description of ERP studies on self-processing). For example, Scott et al. (2005) showed that the passive visualization of one's own face elicits increased P3 amplitude in comparison with familiar and unfamiliar faces. In the same line, enhanced mobilization of attention indexed by increased P3 amplitude was observed when participants were passively listening to one's own name in comparison with both frequent and infrequent names unrelated to the self (Berlad & Pratt, 1995). Together, these studies indicate that different categories of self-stimuli (faces, names, self-related autobiographical information) elicit larger amounts of attentional resources than stimuli unrelated to the self, suggesting a prioritized processing of self-related information at both earlier and later stages of information processing. These attentional biases may be related to the enhanced affective salience of self-related stimuli (Brosch, Scherer, Grandjean, & Sander, 2013; Fan et al., 2013; Tacikowski & Nowicka, 2010; Vüilleumier, 2005).

Nonetheless, only a few studies investigated the processing of self-generated voice cues. Voices play a special role in everyday social communication and can be considered the most important class of sounds in our social environment (Belin, Fecteau, & Bédard, 2004; Schweinberger, Kawahara, Simpson, Skuk, & Zäske, 2014). Through speech production, humans are constantly exposed to their own voice and need to constantly monitor the feedback of their own voices in order to detect potential errors and perform adjustments in vocal production to fit the challenges of the social acoustic environment (Eliades & Wang, 2008). Even though some studies suggest that individuals are less accurate in recognizing their own voice than other familiar voices (e.g., Hughes & Nicholson, 2010), probably due to differences in sound transmission when speaking vs. listening to pre-recorded self-generated speech (Maurer & Landis, 1990), people can recognize their own voice above chance level (Nakamura et al., 2001; Rosa et al., 2008). This ability is preserved even in more demanding tasks, such as when voice stimuli are acoustically transformed at the level of pitch and formant frequencies cues (Allen et al., 2005, Allen et al., 2007; Xu et al., 2013). Importantly, acoustic cues, such as fundamental frequency (F0) of phonation (i.e., the perceived pitch) and formant frequencies have been pointed out as fundamental parameters that listeners rely on to discriminate and recognize the identity of self-generated, familiar and unfamiliar voices (Baumann & Belin, 2010; Latinus & Belin, 2012; Latinus et al., 2013; Xu et al., 2013).

Behavioral and brain studies examining self-generated voice processing corroborate differences in the processing of self vs. non-self cues observed for other types of stimuli. For example, when only higher frequencies are retained in the vocal signal, the ability to recognize self-generated voices is enhanced in comparison with other familiar voices (Xu et al., 2013). Furthermore, in comparison with a non-self voice, hearing a self-generated voice elicits increased activation in the left inferior frontal and right anterior cingulate (Allen et al., 2005), right inferior frontal (Kaplan, Aziz-Zadeh, Uddin, & Iacoboni, 2008; Nakamura et al., 2001) and right parainsular brain regions (Nakamura et al., 2001). A recent ERP study suggests that the differentiation between self- and non-self voice cues at the preattentive level occurs very early in information processing, which is reflected in a centro-parietal negativity to self-generated voice deviants in the 70–100 milliseconds (ms) latency window, and in a right temporo-parietal positivity to unfamiliar voice deviants in the same time window (Graux et al., 2013). However, contrary to previous studies that used other types of self-related information (e.g., Gray et al., 2004; Sugiura et al., 2000), recent ERP evidence showed that, when participants are instructed to pay attention to a silent movie whilst ignoring vocal stimuli, the P3a amplitude to task-irrelevant self-generated voice deviants is reduced in comparison with unfamiliar and familiar voice deviants (Graux et al., 2013; Graux et al., 2014). This finding indicates a decrease in attention orienting to self-generated voice stimuli, which might reflect the prioritized processing of others' voices compared to one's own voice in a later stage of information processing (Graux et al., 2013; Graux et al., 2014). Critical differences in task demands between the studies of Graux et al., 2013; Graux et al., 2014 and studies of visual processing of self-related information may have accounted for the apparently contradictory findings. In particular, in the studies of Graux et al., 2013; Graux et al., 2014 the appearance of a deviant voice disrupted the attentional engagement on the primary task (i.e., watching a silent movie). As such, the reported P3a indexes the orienting response to unexpected deviant stimuli (Friedman, Cycowicz, & Gaeta, 2001; Knight, 1996; Spencer et al., 1999; Spencer, Dien, & Donchin, 2001). This orienting response has been described as an involuntary change of attention that is normally evoked by an unpredictable violation in an otherwise unchangeable auditory sequence (Friedman et al., 2001; Knight, 1996; Spencer et al., 1999; Spencer et al., 2001). Nonetheless, the P3 component reported in most of the abovementioned studies on visual self-related information processing (e.g., Berlad & Pratt, 1995; Cygan et al., 2014; Folmer & Yingling, 1997; Gray et al., 2004; Perrin et al., 1999; Scott et al., 2005; Su et al., 2010; Tacikowski & Nowicka, 2010; Tacikowski et al., 2014; Zhao et al., 2011) is thought to index the allocation of high-order attentional resources to a task-relevant event after the cognitive evaluation of the stimulus meaning, i.e., the P3b (Knight, 1996; Polich, 2007; Spencer et al., 1999; Spencer et al., 2001). Of note, Spencer et al., 1999; Spencer et al., 2001 demonstrated that the P3a and the P3b ERP components are dissociable.

In an attempt to solve these discrepancies, we used the ERP methodology to investigate whether a self-generated voice has privileged access to attentional resources in comparison with a non-self voice, when participants are instructed to focus their attention on a sequence of vocal stimuli, presented in a modified version of the oddball task. Participants were asked to identify an infrequent vocal target stimulus interspersed with frequent vocal standards. The oddball design is a very robust and reliable paradigm for eliciting the P3 component in a short amount of time (Herrmann & Knight, 2001; Polich, 2007; Polich & Criado, 2006). Also, this design is highly suitable for controlling for differences in the physical properties between voice stimuli, since it uses a reduced set of individual stimuli which are presented both as standard and deviant stimuli in different experimental blocks. Another main advantage of using the oddball task to probe the attentive processing of SGV and NSV is that it allows the elicitation of the P3 component, with no overt response being required, as participants might be simply asked to mentally count the number of target deviant stimuli (Knight, 2001; Polich, 2007; Polich & Criado, 2006). The aims of this study were threefold: (1) to examine the role of attention in the processing of self-generated and unfamiliar voices, with the focus on the N2 and P3 ERP components; (2) to test the association between ERP correlates of voice processing and voice acoustic properties, considering previous studies demonstrating that both F0 (i.e., the perceived pitch) and formant frequencies are critical acoustic parameters that listeners rely on to process voice identity (Baumann & Belin, 2010; Latinus & Belin, 2012; Latinus et al., 2013; Xu et al., 2013); (3) to examine whether the ability to

elicited by task-relevant deviants, as our task required that participants focused their attention on the sounds and silently counted the infrequent (and task-relevant) vocal stimuli.

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