



The potential link between sense of agency and output monitoring over speech

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ABSTRACT

We investigated output-monitoring errors over speech based on findings in the research on the sense of agency. Several words were presented one-by-one, and we asked participants to say the word aloud, mouth the word, or imagine saying the word aloud. Later, participants were asked whether each word was said aloud. We found that the “said aloud” response was higher for generated words than that for observed words; it was decreased when the pitch of the feedback was lowered but still higher than when no feedback was received, and it was the same when no feedback was received and when feedback was replaced by another’s voice. Furthermore, we found that the “said aloud” response did not decrease even when the altered feedback was received with a short delay. These results were discussed according to the sense of agency and agency memory.

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1. Introduction

It can be very important to correctly judge whether or not you have performed an action. For example, you may fail to take a required medication because you mistakenly judge that you have already taken it, which is called an omission error (Cohen, 1989; Norman, 1981). On the other hand, you may take the medication twice because you incorrectly judge that you have not yet taken it, which is called a repetition error (Cohen, 1989; Norman, 1981). To prevent these kinds of critical errors, many researchers have investigated how we distinguish between what we have done and what we have not done in the context of everyday life; this process is called output monitoring (e.g., Koriat, Pearlman-Avni, & Ben-Zur, 1998; Leynes & Bink, 2002; Marsh & Hicks, 2001). Output monitoring can be considered a special case of source monitoring, which refers to the process of determining the origin of memory (e.g., Johnson, 1988; Johnson, Hashtroudi, & Lindsay, 1993; Mitchell & Johnson, 2009). There are basically two kinds of sources: external sources (i.e., newspaper, TV) and internal sources (i.e., thought, action). Determining if one actually performed an action or only planned to perform it is a type of source monitoring based on two internal sources, which is also called internal–internal source monitoring (Johnson et al., 1993; Leynes, Crawford, & Bink, 2005).

According to the source monitoring framework (SMF, Johnson, 1988; Johnson et al., 1993; Mitchell & Johnson, 2009), source judgments are the result of a complex set of decision processes whereby qualitative memory characteristics are activated, evaluated, and weighed to attribute memories to particular sources (Johnson et al., 1993). For example, with regard to internal–internal source monitoring (output monitoring), information about both cognitive operations during planning an action and sensorimotor information while conducting the action should be needed to determine that the event is not just

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imagined but actually conducted (Leynes et al., 2005). Previous studies in the field of autobiographical memory research showed that there is a phenomenon in which confidence in the occurrence of fictitious events increases after those events have been imagined (imagination inflation: Garry, Manning, Loftus, & Sherman, 1996; Goff, & Roediger, 1998; Thomas, Bulevich, & Loftus, 2003). Conversely, research in the field of internal–external source monitoring on enactment (performed some actions vs. observed an experimenter perform other actions) found that participants were more likely to respond “I did not perform it” when they performed an action facing a mirror compared to when they performed the action with their eyes closed (Hornstein & Mulligan, 2004). These results suggest that elaborate imagination sometimes produces false sensorimotor information to prompt participants to respond, “I did it,” while sensory information sometimes causes participants to confuse what they did with what another person did.

Recently, using internal–external source monitoring about speech (saying aloud vs. hearing another’s voice), many studies showed that schizophrenia patients with auditory verbal hallucinations are more likely to confuse what they have heard and what they have imagined hearing than are those without auditory verbal hallucinations (Brunelin et al., 2006), and schizophrenia patients with auditory verbal hallucinations were more likely than healthy people to misattribute items they generated to “heard” (e.g., Bentall, Baker, & Havers, 1991; Keefe, Arnold, Bayen, McEvoy, & Wilson, 2002; Woodward, Menon, & Whitman, 2007, also see a review by Ditman & Kuperberg, 2005). Furthermore, in the field of output monitoring (saying aloud vs. not saying aloud), Sugimori, Asai, and Tanno (2010) found a negative relationship between auditory hallucination proneness in healthy people (“I often hear a voice speaking my thoughts aloud”) and accuracy in output monitoring about speech (“I read the word aloud” or “I did not read the word aloud”). Considering these results, auditory verbal hallucinations should be highly related to output monitoring errors over speech. However, to our knowledge, there is no previous research focusing on speech and investigating mechanisms of output monitoring over speech.

Schizophrenia might be a disorder of the sense of agency (Frith, 1987, 1992). The sense of agency refers to the online sense of performing an action (i.e., the sense that “I am the one who is causing an action”), as distinguished from the action being performed by someone else (Gallagher, 2000). According to the forward model for speech, which is a part of the computational model of motor control (Frith, 1992; Jones & Fernyhough, 2007; Seal, Aleman, & McGuire, 2004; Wolpert, Ghahramani, & Jordan, 1995), as the speech command is generated in the brain, a parallel efferent copy of this speech command is also issued. The brain integrates the latter with information about the current state of the system to predict the outcome of actually speaking as planned. These authors suggest that the speech is regarded as emanating from the self only when the actual feedback matches the prediction. That is, the efferent copy issued from the intense speech command and appropriate feedback are needed to obtain a sense of agency over speech. In order to investigate the relationship between sense of agency over speech and auditory verbal hallucinations, the online verbal self-monitoring task has been used in which participants were asked whether the voice fed back was their own voice immediately after they spoke aloud each word presented on a PC monitor, and it was revealed that schizophrenia patients with auditory verbal hallucinations were more likely than healthy people to attribute the voice to another person (external misattribution: Cahill, Silbersweig, & Frith, 1996; Johns & McGuire, 1999; Johns, Gregg, Allen, Vythelingum, & McGuire, 2006; Johns et al., 2001).

Using online verbal self-monitoring tasks (e.g., Cahill et al., 1996), previous experiments have shown a positive relationship between auditory hallucination proneness in healthy people and inaccuracy in output monitoring over speech (Sugimori et al., 2010) and the tendency toward external misattribution in schizophrenia patients with auditory hallucinations. In this study, focusing on the findings in the field of sense of agency, we investigated whether those findings were also seen in output monitoring over speech.

In the study of mental simulation, cognitive motor processes such as motor imagery shared the same representations as real motor execution (Jeannerod, 2001) and only mental simulation without executing an action sometimes caused participants to have the online sense of enactment (Decety & Ingvar, 1990; Ruby & Decety, 2001), suggesting that intense motor command and efferent copy sometimes produce the sense “I am conducting the action” regardless of actual enactment. Previous research on source monitoring showed elaborate imagination sometimes causes participants to respond, “I did it” (e.g., Thomas et al., 2003), and even when people were not directly asked to imagine but were asked to paraphrase complex fictitious events, imagination inflation occurred (Sharman, Garry, & Beuke, 2004). Given these findings, we can predict that speech which needs intense simulation would be more likely to be regarded as actually said compared with speech that does not need internal simulation, and vice versa.

With regard to feedback, several studies have shown that the more the frequency of auditory feedback was altered, the less people responded, “I am the person who is speaking now” in online verbal self-monitoring tasks (e.g., Cahill et al., 1996). That is, participants had more difficulty having a sense of agency over speech when their speech was not presented as predicted than when it was. Source monitoring research revealed that sensory information sometimes made participants confuse what they did with what another person did. Therefore, our second prediction was that participants would be less likely to attribute speech to themselves (“I said it aloud”) when hearing someone else’s voice as feedback in which not only the frequency but also intonation and rate are totally different from their own voice than when they heard their own altered voice as feedback.

On the other hand, some biased feedback might not affect the online sense of agency. In developmental studies, four-year-old children could attribute video feedback of their own figures to themselves with a short temporal delay (Miyazaki & Hiraki, 2006), indicating that the online sense of performing could be sustainable with short delays (e.g., Asai & Tanno, 2007). In addition, when participants received delayed feedback of their speech, they could not speak fluently (Goldberg, Gold, Coppola, & Weinberger, 1997) because they recognized the delayed feedback voice as their own and confused the

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