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The ecology of self-monitoring effects on memory of verbal productions: Does speaking to someone make a difference?

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ABSTRACT

Experiments involving verbal self-monitoring show that memory for spoken words varies with types of sensory feedback: memory is better when words are spoken aloud than when they are lip-synched or covertly produced. Such effects can be explained by the Central Monitoring Theory (CMT) via a process that matches a forward model reflecting expected sensory effects of practiced forms and sensory information during speech. But CMT oversees factors of shared attention as achieved by speaker–listener gaze, and implies that sensory feedback may not affect the learning of unpracticed forms (non-words). These aspects of CMT were examined in two experiments of self-monitoring focusing on oro-sensory feedback. In Experiment 1 we show that varying feedback creates differential effects on memory for spoken words and that speaker–listener gaze alters these effects. Using non-words, Experiment 2 shows the absence of differential feedback effects. The results confirm CMT but suggest the need to refine the theory in terms of processes that mediate attention.

1. Introduction

When performing goal-oriented actions, our movements have sensory effects like feeling our hand grasping a glass or hearing sounds as we speak. This sensory feedback not only serves to guide the execution of movements; it also contributes to form a memory trace of our actions and a sense of having produced the movements. Research on this *sense of agency* (as defined by Gallagher, 2000) is of interest in evaluating how different sensory modalities can impact the learning of actions, including verbal expressions. It is also of interest in understanding certain psychiatric disorders. For instance, a body of work has shown that individuals with schizophrenia have difficulty in differentiating what one said aloud from what was heard to be said by another (for reviews, see Daprati, Nico, Franck, & Sirigu, 2003; Ditman & Kuperberg, 2005).

However, given that people's memory of their daily activities varies considerably (Johnson, 1997), one might question whether their sense of agency is at all useful in evaluating effects of sensory feedback on recalled actions. On this point, Synofzik, Vosgerau, and Newen (2008a,b) have argued that subjects' knowledge of agency can rest on a two-step process. The first step involves a largely unconscious sensorimotor monitoring that occurs while performing actions (an on-line "feeling of agency"). This is followed by a reflective process (an explicit "judgment of agency") based on a memory of action events (but cf. Carruthers, 2009). On this view, there is substantial evidence that judgments of agency entail a monitoring of sensorimotor information that enhances memory of self-generated actions (for reviews, see David, 2010; David, Newen, &

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Vogeley, 2008). This is perhaps most clearly demonstrated in studies that use tasks of *verbal self-monitoring* which show that words produced aloud present a more robust memory trace compared to those that are covertly spoken or spoken by others (e.g. Daprati et al., 2003; Sugimori, Asai, & Tanno, 2011). Hence, these production effects suggest that a monitoring of sensorimotor feedback enhances memory of one's actions.

In examining these enhancing effects with respect to verbal expression, the present study brings to light how speaker-hearer interaction can alter effects of sensory feedback on memory of spoken items as revealed in tasks of self-monitoring. Such effects have not been the focus of theories of agency, which refer mostly to non-verbal behaviors (David, 2010; David et al., 2008). In fact, the question of whether the communicative context alters effects of sensorimotor feedback on verbal memory remains largely unexplored. To further explain the issue, we briefly discuss how current theories of agency account for production effects on memory of spoken forms but do not weigh contextual factors of speaker-hearer interaction.

1.1. Memory of produced forms: accounting for the effects of sensorimotor feedback

Currently, the dominant account of the sense of agency is the "central monitoring theory" (CMT) of Frith, Blakemore, and Wolpert (2000); Frith, 2005), which draws upon studies of motor control and learning (Blakemore, Wolpert, & Frith, 1998; Blakemore, Frith, & Wolpert, 2001; Frith, 1992; Kawato, 1999; Wolpert, Ghahramani, & Jordan, 1995). The basic tenet of CMT is that sensations accompany self-generated motions so that, in repeating actions, sensory effects become predictably linked to motor commands and can thus provide perceptual cues to agency. In terms of motor-control principles, CMT states that, in performing practiced actions, efferent signals to motor processes generate a parallel efferent copy or "reafference copy" (von Holst & Mittelstaedt, 1950). This constitutes a *forward model* serving to predict sensory consequences of movements. Upon producing actions, the model is compared against actual sensory effects. If the two correspond, then sensory effects are inhibited, and this enables a differentiation between a memory of *self-generated* sensations and externally generated sensations (for details, see Blakemore, Wolpert, & Frith, 2000). In developing this view, Frith, Rees, and Friston (1998) recognized that a weakness of the central monitoring hypothesis was that it only dealt with overt motions whereas covert actions can also impact memory and agency judgments. For instance, it is known that imagining motions can enhance the learning of actions (Jeannerod, 1995) so, presumably, an internal model can be generated without overt actions (see, e.g. Wolpert, Ghahramani, & Flanagan, 2001). Blakemore, Wolpert, and Frith (2002) suggest that, in this type of learning, subjects choose motor commands that are most likely to achieve a desired state (an *inverse model*). Though this information is not sent to motor processes, it serves to develop a forward model by which to compare the sensory effects of commands. If the expected effects of performed actions do not match the desired result, then the motor commands are modified, and learning takes place.

It is worth noting that CMT theory is most directly relatable to the workings of the cerebellum and parietal cortex (including the inferior parietal lobule and posterior parietal cortex; Blakemore et al., 2001; see the reviews of David (2010), Ito (2012) and Koziol, Budding, and Chidekel (2012)). As summarized by Koziol et al. (2012), there is a consensus on the point that internal models of action develop in the cerebellum via the cerebro-cerebellar circuitry and the system of mossy fiber. These structures allow the cerebellum to copy the contents of conscious working memory (Ito, 2005). Thus, the learning of new actions or action sequences first develops consciously and involves signals from premotor and primary motor cortices, and the temporo-parietal cortex (on the differing roles of the cerebellum and parietal cortex in developing a sense of agency, see David, 2010). As learning proceeds, the parietal cortex acquires a "body schema" and a "motor schema" (cf. Daprati, Sirigu, & Nico, 2010), which are copied by the cerebellum in forming internal models. Hence, the models consists of all of the dynamic sensory and motor information necessary to produce a movement, and this model is adjusted as movements are repeated (Ito, 2008). Finally, the cerebro-cerebellar circuitry projects the most efficient behavior to motor regions of the cortex, which stores it (see Doyon et al., 2002; Galea, Vazquez, Pasricha, de Xivry, & Celnik, 2011; Houk et al., 2007; Koziol et al., 2012). As for verbal productions, the monitoring of feedback during the self-generated speech is seen to involve the same network of structures as the monitoring of externally generated speech (McGuire, Silbersweig, & Frith, 1996). Reports show that normal feedback during speech as opposed to altered feedback is associated with an inhibition of activity in the temporo-parietal cortex (namely, the auditory cortex). This conforms precisely to CMT on the point that sensory effects of self-generated motions are inhibited (e.g., Christoffels, van de Ven, Waldorp, Formisano, & Schiller, 2011; Fu et al., 2006).

1.2. Unexamined implications of CMT on the learning of verbal forms: the present study

In sum, the above discussion bears out the substantial amount of evidence supporting the central monitoring account. However, extending this account to self-monitoring effects on memory of verbal forms leads to unexamined assumptions with far-reaching implications for language learning. One pivotal assumption is that the varied sensorimotor feedback of speech production would remain unspecific when it comes to learning *novel* verbal items. This is because, according to the above principles, sensorimotor schemata at the cortical level may not be fully developed for unpracticed sequences of syllables constituting new verbal forms. Consequently, there would be no precise forward model by which to compare predicted and actual sensory information of production. This viewpoint leads to specific predictions in terms of