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Response mode does not modulate the space–time congruency effect: Evidence for a space–time mapping at a conceptual level

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ABSTRACT

Previous studies reported a space–time congruency effect on response time, supporting the notion that people's thinking about time is grounded in their spatial sensorimotor experience. According to a strong view of metaphoric mapping, the congruency effect should be larger for responses that differ in their spatial features than for responses that lack such differences. In contrast, a weaker version of this account posits that the grounding of time is based on higher-level spatial concepts. In this case, response mode should not modulate the size of the space–time congruency effect. In order to assess these predictions, participants in this study responded to temporal stimuli either manually or vocally. Response mode did not modulate the space–time congruency effect which supports the weaker view of metaphoric mapping suggesting that this effect emerges at a higher cognitive level.

1. Introduction

According to a prominent view in linguistics, philosophy, and cognitive psychology, people rely on spatial concepts when they talk and think about time (e.g., Casasanto, Fotakopoulou, & Boroditsky, 2010; Evans, 2004; Fraser, 1966; Haspelmath, 1997; Klein, 2009; Tversky, Kugelmass, & Winter, 1991). Specifically, it is assumed that spatial concepts are necessary to structure our thinking about time, because time is an abstract concept and is thus not directly accessible via our senses (e.g., Grondin, 2001). In contrast, spatial concepts are structured by sensory and motor experiences and it is this structure that is inherited by the domain of time. This metaphoric mapping of space onto time has been called the *spatial metaphor of time* (e.g., Clark, 1973a).

The spatial metaphor of time is consistent with the notion of *grounded cognition*. Grounded cognition refutes the classical sandwich view (Hurley, 1998, p. 406) of cognition, which proceeds from the assumption of a functionally encapsulated system of cognition that receives input from perception and outputs its information to the motor system. Although there are diverse views of grounded cognition, they all share the notion that cognition is closely interwoven with sensorimotor experiences (see Barsalou, 2008; Wilson, 2002). The grounded cognition framework is supported by findings of neurophysiological studies that indicate the involvement of motor circuits during the processing of linguistic material (for a review, see Gallese & Lakoff, 2005; however, see Kranjec & Chatterjee, 2010; Miller & Brookie, 2012; Walsh, 2003). Furthermore, reading words like *salt* automatically activates brain regions that are involved in the processing of gustatory stimuli (Barrós-Loscertales et al., 2012). At a behavioral level, Glenberg and Kaschak (2002) demonstrated that the processing of sentence meaning interacts with the execution of manual responses. Similar findings were reported for the processing of word meaning (e.g., Dudschig, Lachmair, de la Vega, De Filippis, & Kaup, 2012). It is difficult to imagine how such results would emerge within the classical sandwich view of cognition as they clearly indicate a linkage of cognition and sensorimotor processes. According to the metaphoric mapping account of grounded cognition, however, even abstract concepts, like justice or love, are thought to be linked to sensorimotor experience (Lakoff & Johnson, 1980). Thus the mapping of space onto time is just one example of this general principle.

The idea that spatial concepts underlie our thinking about time has received strong support from reaction time (RT) studies (e.g., Santiago, Lupiáñez, Pérez, & Funes, 2007; Torralbo, Santiago, & Lupiáñez, 2006; Ulrich & Maienborn, 2010; Weger & Pratt, 2008). For example, in the study of Torralbo et al. (2006), participants responded to time-related information with a keypress on the left or right side. In the congruent condition, they responded to future-related information with a keypress on the right side with the right hand and to past-related information with a keypress on the left side with the left hand. In the incongruent condition, this stimulus–response (S–R) mapping was reversed. A space–time congruency effect was found; that is, RT was shorter in the congruent than in the incongruent condition. This congruency effect has been interpreted in terms of a mental timeline that runs from left to right.

Studies following Torralbo et al. (2006) have predominantly examined this left–right space–time congruency effect (e.g., Santiago et al., 2007; Ulrich & Maienborn, 2010; Weger & Pratt, 2008) and replicated

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it for different types of linguistic material. In addition, further studies have reported a space–time congruency effect on the front–back axis (Sell & Kaschak, 2011; Torralbo et al., 2006; Ulrich et al., 2012). Specifically, faster responses were observed when participants responded to future-related linguistic information with a forward movement and to past-related information with a backward movement, compared to when this mapping was reversed. This supports the existence of an additional mental timeline that runs from back to front.

As yet, the basis of these space–time congruency effects has not been addressed. At present, two alternatives based on a distinction between a weak and a strong view of metaphoric mapping seem to be possible. Both views share the assumption that bodily experiences are obligatory to enable mental representations. For the case of time this means that sensorimotor processes involved in the perception of and interaction with space (e.g., visual depth perception, self-motion in space) are essential building blocks of our mental representation of time. The strong view of metaphoric mapping presupposes that sensorimotor mechanisms are not only necessary to establish a mental representation but are also functionally involved whenever this mental representation is activated. In other words, thinking about abstract entities would be impossible without activating these low-level mechanisms. In particular, sensorimotor mechanisms that originate from our experience with space should be involved in the processing of temporal information and consequently in the emergence of the space–time congruency effect (e.g., Boroditsky, 2000; Gallese & Lakoff, 2005).

If the mental representation of time depends on low-level sensorimotor processes, as this strong view proposes, one would expect that the nature of the response modulates the size of the congruency effect because particular low-level sensorimotor processes are associated with particular response modes (e.g., vocal versus manual responses). For instance, manual response alternatives can differ in their spatial location whereas vocal responses cannot. Therefore manual response alternatives are usually defined by their spatial features (e.g., response location, or movement direction; see Rosenbaum, 1980) and consequently comprise sensorimotor processes related to space (e.g., response with the left vs. right hand, or forward vs. backward movements). On the other hand, vocal responses (e.g., the spoken words “left” vs. “right” or “forward” vs. “backward”) do not differ in their external spatial features, that is, the spatial location of vocal responses is always the same. Nevertheless, vocal responses referring to space (e.g., “left”, “right”, etc.) can convey abstract spatial information, as the words themselves contain spatial meaning. It is known that the size of S–R congruency effects increases with the number of features that are shared by responses and stimuli (Kornblum, Hasbroucq, & Osman, 1990, p. 259). Therefore one would expect a larger space–time congruency effect if both temporal stimuli and spatial responses share the same low-level sensorimotor features than when they do not. Consequently, the strong view suggests a larger space–time congruency effect for manual than for vocal responses.[1]

In contrast to the strong view, the weaker view of metaphoric mapping assumes that sensorimotor experiences are necessary only to establish the mental representation of time (Boroditsky, 2000). Once this representation is established, it is no longer functionally linked to those low-level sensorimotor processes. Therefore, this view postulates that the space–time congruency effect only reflects conceptual associations between time and space at higher cognitive levels. According to this view, spatial features of the response should not modulate the space–time congruency effect.

As far as we know, evidence for either of these two views is scarce. The strong view is in line with findings reported by Sell and Kaschak (2011). They observed a space–time congruency effect when participants were required to make an arm movement but no congruency effect when participants were required to make discrete keypresses (i.e. single keypresses, without preceding arm or hand movements toward the key), which indicates that response mode can modulate the congruency effect. Furthermore, Weger and Pratt (2008) report a spatial priming effect of time-related words which depends on response type. They used time-related words to prime the location of a subsequent target on the screen. A priming effect was observed only when participants responded with a left or right keypress to the location of the target but not when the target had to be detected in a simple RT task without spatially defined response alternatives. These results suggest that response mode even plays a major role in the occurrence of space–time congruency. Evidence consistent with the weak view has been reported by Ulrich et al. (2012). They found that motor features of manual responses, such as movement duration, are insensitive to a manipulation of space–time congruency, which suggests that the peripheral motor system is not involved in the emergence of the space–time congruency effect. Therefore the present evidence concerning the basis of the space–time congruency effect is inconclusive.

It should be stressed, however, that previous experiments did not aim to address this issue directly. Although a space–time congruency effect has been reported for vocal responses (Eikmeier, Schröter, Maienborn, Alex-Ruf, & Ulrich, 2013; Torralbo et al., 2006), discrete keypresses (e.g., Santiago et al., 2007; Weger & Pratt, 2008) and arm movements (e.g., Sell & Kaschak, 2011; Ulrich & Maienborn, 2010), until now there has been no study that directly compares the size of the space–time congruency effect for different response modes.

The present experiment was designed to examine whether the spatial characteristics of the response modulate the size of the space–time congruency effect as predicted by the strong view of metaphoric mapping. To this end, we manipulated the response mode, while keeping all other aspects in our RT paradigm constant. Specifically, in one experimental condition, the responses were vocal, whereas in the other condition, the responses were manual movements. The strong view predicts a larger congruency effect for manual than for vocal responses, whereas the weak view predicts that the effect should not be modulated by response modality.

2. Experiment

Identical stimuli (words referring to past or future like *yesterday* or *tomorrow*) were employed in the manual and in the vocal condition of this experiment. All participants performed both response conditions. The mapping of the stimuli onto the responses was either congruent (i.e., *yesterday* → back response; *tomorrow* → front response) or incongruent (i.e., *tomorrow* → back response; *yesterday* → front response). All stimuli were presented auditorily to prevent eye movements during reading which might contaminate the RT results. The stimulus set also included pseudowords as no-go trials. These trials were included to emulate our previous studies on the space–time congruency effect for time-related sentences (Ulrich & Maienborn, 2010; Ulrich et al., 2012) in order to allow a comparison of results.

2.1. Method

2.1.1. Rating study

To make sure that the words used as stimuli in the experiment clearly referred to past or future, a rating study was conducted. Twenty volunteers (mean age = 25.3 years, all native speakers of German) who did not take part in the main experiment rated a list of 92 time-related German expressions (18 neutral fillers, 35 future-related, and 36 past-related). The items of the list were presented in random order and

[1] Note that the strong view of metaphoric mapping does not exclude additional time–space associations at a conceptual level. These associations may cause a space–time congruency effect also for vocal responses. As the vocal responses do not share low-level sensorimotor features with the stimuli, a space–time congruency effect with vocal responses should, however, still be smaller than a space–time congruency effect with manual responses.