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Task-dependent motor representations evoked by spatial words: Implications for embodied accounts of word meaning

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ABSTRACT

Embodied accounts contend that word meaning is grounded in sensorimotor representation. In support of this view, research has found rapid motor priming effects on vertical movements for words like *eagle* or *shoe*, which differ as to whether they are typically associated with an up or down spatial direction. These priming effects are held to be the result of motor representations evoked as an obligatory part of understanding the meaning of a word. In a series of experiments, we show that prime words associated with up or down spatial locations produce vertical perturbations in the horizontal movements of a computer mouse, but that these effects are contingent either on directing conscious attention to the spatial meaning of the word, or on the inclusion of the primed spatial direction in the response set, and that this is true even for strongly spatial words such as *up* and *down*. These results show that the motor representations associated with such words are not automatically evoked during reading. We discuss implications for claims that spatial representations reflect our embodied perception of the world.

Introduction

The meaning of spatial prepositions like *above* and *below* can influence the selection of an up/down movement. For example, the word *above* acting as a prime, induces faster and more accurate upward than downward responses, whereas the word *below* yields the opposite result (Ansorge, Khalid, & König, 2013). More surprisingly, analogous results have been reported for words like *bird* and *submarine* that, although not explicitly concerned with spatial location, nonetheless affect speeded responding in an up/down direction (e.g. Dudschig, de la Vega, De Filippis, & Kaup, 2014; Dudschig, Lachmair, de la Vega, De Filippis, & Kaup, 2012; Lebois, Wilson-Mendenhall, & Barsalou, 2015). We will refer to such words for convenience as UP/DOWN words. The evidence suggests that many words, at least under certain task conditions, trigger spatial representations associated with our experiences of objects; birds are often encountered above us in the sky, whereas submarines move below in the depths of the ocean.

Spatial compatibility effects induced by language are often taken as support for the claim that meaning is grounded in sensorimotor representations, including representations dealing with an object's typical location in space. For example, Ansorge, Kiefer, Khalid, Grassl, and König (2010) used a set of six spatial prepositions like *above* and *below*, and two adjectives (*high* and *deep*) as both masked primes and as targets. Subjects were required to indicate by means of an upper or lower keypress made from a neutral starting point whether target words referred to an upward or downward spatial position or direction. Semantic congruency effects on speeded responding were found even though the primes were pre-

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sented too briefly for conscious report. According to the authors, their findings are consistent with "...mandatory sensorimotor processing of words when accessing their meaning" (p. 303). A similar result was obtained by Dudschig et al. (2014), who found priming effects for subliminally presented UP/DOWN words on the speed and accuracy of upward/downward responses to color cues. The authors concluded that "...language-action interconnections are automatically activated ... (when) ... processing a very wide set of linguistic stimuli, even in paradigms that limit strategic language processing to a minimum" (p. 156).

In contrast, Lebois et al. (2015) found no evidence that UP/DOWN words acting as primes influenced performance when the task simply involved speeded up/down responding to a color cue. Rather, an explicit decision about word meaning was needed to yield spatial priming effects. Because these authors repeatedly failed to find congruency effects under well-defined task conditions that involved no explicit attention to the meaning of words, Lebois et al. rejected the claim that spatial congruency effects are automatic. They argued instead that a variety of conditions might tacitly have increased the accessibility of spatial features in other studies. For example, the requirement to engage in up/down keypress responses to a color cue (e.g. Dudschig et al., 2014) may well have oriented subjects to verticality as a response dimension, establishing a context that dynamically activated the spatial features of words. A version of this idea could even apply when the priming words are presented too quickly for conscious report. Task set influences the way unconscious stimuli are processed (e.g., Ansorge et al., 2010; Kunde, Kiesel, & Hoffmann, 2003), a consideration leading Dudschig et al. (2014) to acknowledge in their study that "... even the mounting of the response apparatus in the vertical dimension might activate specific response codes that ... influenced how the words were unconsciously processed (p. 156)." Lebois et al. (2015) noted that their response apparatus was positioned on the right of the computer screen, a departure from the more conventional position centered along the midline. This spatial arrangement would force subjects to glance back and forth horizontally when producing a response. The need to engage in this left-right orienting may have rendered verticality a less salient dimension, triggered only by instructions to explicitly process the meaning of words.

In this article, we seek to further evaluate the conditions that determine the influence of spatial words on movement in a vertical direction. Our methodological approach reduces the influence of task demands emphasizing up versus down as the intended response, while still allowing us to measure subtle effects of a word on the vertical component of a movement. Consider moving a cursor horizontally on a screen by means of a computer mouse, from a central position to one of two locations placed some distance to the left or right of the starting point. Although the requirement is ostensibly to move the cursor along a horizontal axis, the trajectories will immediately reveal that the movements include a definite vertical component. In general, there are obvious deviations along the vertical axis as the hand moves the cursor horizontally.

Note that, because the mouse lies on the flat surface of the table, an upward movement of the cursor actually requires a forward extension of the arm and a downward movement of the cursor requires flexion of the arm. This introduces a possible complication in that the relationship between the primed spatial direction and the associated motor action is indirect; the up/downward movement of the cursor corresponds to extension and flexion of the arm. We assume, however, that the motor system may directly convert arm movements into a representation of the resulting cursor movement. There is indeed neurophysiological evidence that supports this assumption. Ochiai, Mushiake, and Tanji (2005) projected an image of a monkey's hand onto a computer screen, and required the monkey to move the image to a target location presented at various angles relative to a starting position. In one condition, the image was mirror reversed relative to the monkey's hand, so that the direction of motion on screen was opposite to the actual motion of the hand. Some of the neuron populations in the ventral premotor cortex coded for the direction of image motion, and not the motion of the hand itself. The authors concluded that "...[ventral premotor] neurons play a crucial role in determining which part of the body moves in which direction, at least under conditions in which a visual image of a limb is used to guide limb movements" (p. 929). We assume that a similar principle applies when limb movement is guided by the image of a cursor.

Our methodology is based on the conjecture that under certain task conditions, the extent of the vertical deviation of a horizontal cursor movement should be influenced by the priming of spatial features representing an upward or downward direction. Evidence supports our assumption. Tower-Richardi, Brunyé, Gagnon, Mahoney, and Taylor (2012) had subjects use a computer mouse to move a cursor to one of four rectangular target boxes situated to the left, right, above, and below a central start box. Cued movements were produced in response to the words *up*, *down*, *left* or *right* and the words *north*, *south*, *west* or *east* acted as briefly occurring primes. The word *east* biased vertical target movement trajectories to the right, and *west* biased these trajectories to the left. The word *north* biased the trajectory of horizontal movements upward, whereas *south* biased the horizontal trajectory downward. Additional support for the idea that words can prime movement in a direction orthogonal to a cued trajectory was provided by Zwaan, Van der Stoep, Guadalupe, and Bouwmeester (2012). These authors required subjects standing or seated on a Wii balance board to indicate whether a sentence was sensible or not by moving the board sideways (e.g. left for sensible, right for non-sensible). The sentences implied movement in a forward (e.g., *John bent to tie his shoelaces*) or backward direction (e.g., *John braced himself in the tug of war*). Because the balance board provided spatio-temporal co-ordinates that included forward/backward components of movement, it was possible to determine from the trajectories whether the sentences activated spatial representations consistent with their meaning, even though the task ostensibly involved leaning only to the left or right. Depending on the forward/backward direction implied by the sentences, the sideways trajectory of the response