Acta Psychologica 156 (2015) 126–135

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Musical metaphors: Evidence for a spatial grounding of non-literal sentences describing auditory events☆

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ARTICLE INFO

Available online 18 October 2014

PsycINFO classification:
2100
2300
2340
2700
2720

Keywords:
Literal vs. non-literal language
Embodied cognition
Spatial processing
Metaphors

ABSTRACT

This study investigated whether the spatial terms *high* and *low*, when used in sentence contexts implying a non-literal interpretation, trigger similar spatial associations as would have been expected from the literal meaning of the words. In three experiments, participants read sentences describing either a high or a low auditory event (e.g., *The soprano sings a high aria* vs. *The pianist plays a low note*). In all Experiments, participants were asked to judge (yes/no) whether the sentences were meaningful by means of up/down (Experiments 1 and 2) or left/right (Experiment 3) key press responses. Contrary to previous studies reporting that metaphorical language understanding differs from literal language understanding with regard to simulation effects, the results show compatibility effects between sentence implied pitch height and response location. The results are in line with grounded models of language comprehension proposing that sensory motor experiences are being elicited when processing literal as well as non-literal sentences.

1. Introduction

A recent approach in language comprehension research suggests that comprehension is inevitably linked to sensory-motor experiences (Barsalou, 1999). Specifically, experiences acquired during interactions with the world leave traces in the brain, which are retrieved and used as mental simulations during language comprehension processes. Based on these assumptions, it is postulated that words and other linguistic descriptions serve as cues activating experiential traces stored in long-term memory that subsequently build the basis of understanding (Zwaan & Madden, 2005). This approach contradicts traditional accounts of language comprehension which postulate an arbitrary and abstract knowledge representation. In this latter view it is proposed that language understanding is based on abstract symbols, which do not share any similarity with their referents in the real world (e.g., Chomsky, 1957; Kintsch & Van Dijk, 1978).

Substantial support for the simulation framework comes from behavioral, neurophysiological and imaging studies. For example, in fMRI studies it has been demonstrated that action words, such as *kicking* or *picking*, activate areas in the premotor cortex which are also active when actual foot or arm movements are being performed (Hauk, Johnsrude, & Pulvermuller, 2004; Raposo, Moss, Stamatakis, & Tyler, 2009). Analogously, it has been found that reading smell or taste related words, such as *salt* or *cinnamon* activates the corresponding gustatory or olfactory brain regions (Barrós-Loscertales et al., 2012; González et al., 2006). Using behavioral paradigms, Glenberg and Kaschak (2002) found that after reading sentences that implied a movement towards or away from the body (e.g., *Open the drawer* vs. *Close the drawer*), participants were faster performing arm movements in a compatible compared to an incompatible direction (e.g., moving towards compared to away from the body after reading a sentence such as *open the drawer*). Recently, increasing evidence for the reactivation of sensorimotor experiential traces during language processing has been drawn from studies investigating words referring to entities or situations with particular spatial properties. For example, it has been shown that nouns referring to entities with a typical location in the vertical dimension (e.g., *sun* vs. *worm*) or verbs referring to physical motions (e.g., *rise* vs. *fall*), automatically activated responses towards locations that are compatible with the referents' location in the real world. Thus, upward arm or eye movements were faster following a word such as *sun* or *rise* than following a word such as *worm* or *fall* (Dudschig, de la Vega, & Kaup, 2014; Dudschig, Lachmair, de la Vega, De Filippis, & Kaup, 2012; Dudschig, Souman, Lachmair, de la Vega, & Kaup, 2013; Lachmair, Dudschig, De Filippis, de la Vega, & Kaup, 2011). To date, the involvement of sensory and motor activation during language processing has been demonstrated for a wide spectrum of phenomena, including also the color, shape

☆ We thank Eduard Berndt, Matthias Hüttner, Johanna Lechner, Teresa Martin and Lukas Eschstruth for the data collection. This work was supported by a research grant from the German Research Foundation (DFG) to Barbara Kaup and Hartmut Leuthold (SFB 833, project B4).

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http://dx.doi.org/10.1016/j.actpsy.2014.09.006

and touch of objects (Bub, Masson, & Cree, 2008; Connell, 2007; Connell & Lynott, 2009; Masson & Bub, 2008; Zwaan, Stanfield, & Yaxley, 2002). Moreover, there is evidence that even abstract concepts, such as time, become associated with sensory experiences, for example via a mapping onto physical space (e.g., Lakoff & Johnson, 1980; Santiago, Lupiáñez, Pérez, & Funes, 2007; Ulrich & Maienborn, 2010). Taken together, these findings support the assumptions of the simulation framework that language and thought are grounded in sensory-motor experiences with the world, one's body and mind (Barsalou, 2008).

Despite a growing body of evidence supporting the importance of sensory-motor representations during language understanding, there is an ongoing debate regarding the question how non-literal or metaphorical language is understood. Several studies found differences in processing depending on whether a word is used in a literal compared to a metaphorical context (Bergen, Lindsay, Matlock, & Narayanan, 2007; Raposo et al., 2009). In their study, Raposo et al. (2009) used three types of stimuli: single action verbs such as *grab* or *trample*, the same action words embedded within a sentence context supporting the literal meaning of the verb, for example, *the fruit cake was the last one so Claire grabbed it*, and sentences providing an idiomatic context such as *the job offer was a great chance so Claire grabbed it*. Raposo et al. (2009) found that hearing single action verbs as well as hearing sentences supporting the literal meaning of the action verb led to an activation of the corresponding body-related motor region in the brain. On the contrary, when action verbs were embedded within an idiomatic context, no activation was shown. Similarly, Bergen et al. (2007) found that reading literal motion sentences such as *the mule climbed* led to interference processes in a visual perception task whereas reading metaphorical sentences with the same action verbs such as *the oil price climbed* did not. Taken together these studies suggest that processing action words such as *grab* or *climb* only activates corresponding motor regions when the action verb occurs in a sentence which is consistent with the literal meaning of the relevant verb. In case the sentence does not support a literal interpretation of the verb, but rather suggests a metaphorical interpretation, motor regions are not being activated. The authors therefore conclude that simulation processes are based on sentence interpretation and do not just reflect an activation of the lexical semantics of single words. The authors moreover assume that metaphorical sentences differ from literal sentences with regard to mental simulation processes. This assumption, however, seems to stand in conflict with metaphor theories suggesting that metaphorical descriptions are used to express abstract concepts in more tangible, experiential forms in order to help us structure and understand the underlying meaning (Lakoff & Johnson, 1980). Matlock (2004), for example, showed simulation effects for fictive motion sentences, such as *the fence runs across the property line*, with motion verbs (here *run*) used in a non-literal way. In her experiments she found shorter reading times for fictive motion sentences when a travel along a path had previously been described as involving a short compared to a long distance (Experiment 1) or a fast compared to a slow movement (Experiment 2). This shows that sentences that are not related to any explicit motion nevertheless may show an association with an implicit movement during sentence comprehension.

The question regarding the reactivation of primary sensory experiences in the case of sentences that do not imply literal interpretations is of great interest for the grounded model of language understanding. However, it is yet unclear how metaphorical language is represented and eventually understood during language comprehension. In particular, it remains open how the typically rather strong word-based simulation effects can be overcome by sentential interpretations. Additionally, with regard to the simulation view of language understanding the question arises how these metaphorical sentences can be understood if they do not result in a reactivation of sensory experiences, which are typically suggested to underlie language comprehension processes (e.g., Zwaan & Madden, 2005). In the present study we therefore aimed at further investigating the question whether or not evidence can be obtained for the involvement of sensory motor experiences when processing non-literal sentences. We employed an experimental paradigm and a stimulus dimension for which simulation effects have been observed with isolated words and in literal sentences (e.g., Dudschig et al., 2012; Lachmair et al., 2011). Specifically, it was investigated whether responses in vertical space (up vs. down key presses, see above) are affected by particular spatial terms mentioned in a non-spatial context.

A word group that is particularly interesting for investigating the questions raised are the spatial terms *high* and *low*. In the first place, the terms *high* and *low* are spatial terms that are commonly used for categorizing space. Interestingly, when describing sounds we also often use the terms *high* and *low*, in particular when the sound's pitch is important. Thus, we may for instance say that the flute played a high tone or that the machine emitted a low sound. Referring to pitch in purely spatial terms therefore suggests a non-literal interpretation of the words *high* and *low*, as musical pitch in principle does not imply a spatial location (e.g., Eitan & Timmers, 2010). Indeed, in other cultures high and low pitched tones are referred to differently, for example as being small or large (van Zanten, 1986, p. 85) or thick and thin (Dolscheid, Shayan, Majid, & Casasanto, 2013). Describing pitch relations in terms of vertical space has become a convention in Western traditions since the Middle Ages (Zbikowski, 2002, p. 63). It reflects a cognitive mapping of two different domains (space and pitch height), a state of affairs that is often referred to as a conceptual metaphor (Lakoff & Johnson, 1980; Zbikowski, 2002, p. 66). Thus, language describing auditory events provides an ideal opportunity to investigate spatial simulation effects in situations where the word is used in a non-literal context. If the spatial words *high* and *low* reactivate sensorimotor spatial associations, even if embedded in sentences referring to pitch height, this suggests that basic sensorimotor associations also become activated during non-literal, metaphorical language understanding. At the moment only little is known regarding the representation of sound during language processing. First evidence suggests that while reading sound related words, such as for instance the word *telephone*, the auditory cortex becomes activated (Kiefer, Sim, Herrnberger, Grothe, & Hoenig, 2008). Additionally, Brunyé, Ditman, Mahoney, Walters, and Taylor (2010) found that when reading sentences implying specific auditory sounds, judging a subsequent auditory sound as real versus fake was faster when the sound matched the sentence.

In the present study we investigated whether the words *high* and *low* used in a sentential context referring to pitch height trigger vertical spatial associations as would be expected from the literal meaning of the words *high* and *low*. According to the results by Bergen et al. (2007), no such effects are to be expected because the sentential context does not support the literal meaning of the words *high* and *low* but establishes a metaphorical interpretation based on pitch height. If instead the words still activate their original spatial experiences even when used in a non-literal context then sentences describing auditory events including the words *high* and *low* should result in compatibility effects with up and down responses. To test this hypothesis, sentences with the words *high* and *low* were constructed that described sounds of different pitch heights stemming from musical instruments, singers, animals or environmental sounds (e.g., thunder). The described sounds were easily distinguishable as low auditory events (e.g., *The pianist plays a low note*) or high auditory events (e.g., *The soprano singer sings a high Aria*). In addition to these explicit sentences, in which the words *high* and *low* were used to describe sounds of different pitch level, we also presented implicit sentences in which pitch height was only implied (e.g., *The parrot screeches shrilly* vs. *The turbines are emitting a hollow drone*). The implicit sentences were added in order to see whether the words *high* and *low* in the sentences are essential for activating spatial experiences during language comprehension. In principle it also seems conceivable that spatial associations are automatically activated as soon as a sentence describes an auditory event of a particular pitch height, even when the sentence does not explicitly mention any spatial terms.