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Language unifies relational coding: The roles of label acquisition and accessibility in making flexible relational judgments

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ABSTRACT

Language is likely structuring spatial judgments, but how it achieves this is not clear. We examined the ability to make relative, spatial judgments across verbal and nonverbal tasks of *above*, *below*, *right* and *left* in children between the ages of 5 and 10 years. We found that the verbal ability to make *above/below* judgments preceded verbal *right/left* judgments and all nonverbal judgments. We also found that only when the labels were *accessed* – as opposed to only having been acquired – did children's nonverbal performance improve. Our findings further indicate that accessing the correct term was not needed for enhanced performance. The results suggest that accessing language unifies different instantiations of a relation into a single representation.

Introduction

The ability to make relational judgments is central to human intelligence because it promotes abstract levels of reasoning and problem solving (Gentner, 2003, 2010; Halford, Wilson, & Philips, 2010). For example, relational knowledge is fundamental in spatial reasoning, which in turn is critical for math and science skills (National Research Council, 2006). By some views, knowledge of language plays a critical role in relational processing. Yet, despite the evidence that language affects relational processing, it remains unclear exactly *how* language might be helping. It is largely believed that as each individual term is learned, it instantly enhances performance across different instantiations of that relation *automatically* without conscious effort, as seen in some Stroop tasks (see Diamond, Kirkham, & Amso, 2002, for discussion). In this case, once a term is learned, it is automatically retrieved and applied in the appropriate contexts. Another possibility, however, is that language *use* is initially needed and improvement in nonverbal judgments is only observed when the labels are *accessed*. In this case, the appropriate terms are available but are not always activated or applied to the task at hand. Only after the terms are entrenched or well-learned would they, then, affect performance effortlessly across different tasks or instantiations of the relation.

The goal of this paper is to better understand the role of language in making dynamic relational judgments. We do this in two ways. First, we examine developing knowledge of a broader set of relations across a broader age span than has been previously studied, both verbally and nonverbally. This enables us to examine the role of language *acquisition* on the ability to make correct relational judgments. Second, we manipulated the *accessibility* of language to examine whether language and its *use* are causal factors in any improvement of relational processing. While several studies have found that language knowledge precedes enhanced performance across other relational tasks, because these studies are largely correlational, it is not clear whether language or an unstudied factor (that is also correlated with language development) is driving the improvement. If language is causing the improvement, however, and not some third factor, then "dialing up" the strength of language should improve performance in nonverbal relational judgment tasks. If another factor is solely responsible for the improvement, then dialing up the role of language should not affect performance. A final issue that we studied was whether the use of any term would suffice, or whether coding with the precise relational terms was necessary for performance to improve. This study, thus, fills important gaps in the evidence on the role of language in the development of the ability to make relational judgments.

Past evidence on the role of language in relational thought

In trying to understand the development of relational knowledge, many researchers have turned to language as a causal factor, but the current evidence regarding the role of language in relational knowledge is mixed. There is some cross-linguistic evidence indicating that language can structure spatial representations. For example, Hespos and colleagues (Hespos & Piccin, 2009; Hespos & Spelke, 2004) found that 5-month-old infants being raised in an English-speaking environment

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were sensitive to *tight* versus *loose* distinctions – a distinction not marked in English, but that is marked in other languages, like Korean. In these studies, English-reared infants behaved like Korean adults, and unlike English adults, in recognizing the *tight-loose* distinction, suggesting that language leads English-speaking adults to ignore the distinction. In other cross-linguistic work on the topic, Levinson (1996) showed that preferred frames of reference are determined by language: whether a language codes spatial information in terms of *north-south* (cardinal) or *left-right* (relational) coordinates effectively determines how speakers represent object locations (see also, Levinson, 2003). Other studies, however, have shown that individuals can override their preferred, native frame of reference for less preferred reference points, in certain situations (Li & Gleitman, 2002). However, such flexibility has not always been found (e.g., Haun, Rapold, Janzen, & Levinson, 2011).

When studying development, or what comes first, considerable evidence suggests that acquiring labels consistently precedes the ability to encode and remember relative object locations (e.g., Loewenstein & Gentner, 2005; Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010). For example, Loewenstein and Gentner (2005) showed that presenting children with the labels *top/middle/bottom* improved their judgments in a search task. Researchers hid a sticker on a shelf and children who were provided a relational term (i.e., "See? I'm hiding the sticker on the middle shelf") to describe the hiding place performed better than children who were instructed with a generic term, like *here*. Casasola (2005) similarly found that priming 18-month-olds – by providing them with a familiar, relational term (*on*) – enabled these infants to categorize instances of support, whereas providing infants with a general verbal command (*Look!*) or no term at all did not aid infants.

Hermer-Vazquez, Moffet, and Munkholm (2001) provide similar evidence indicating that knowing the correct, specific label leads to successful performance in a *right* and *left* reorientation and retrieval task. In their study, preschoolers who could correctly produce the terms *right* and *left* on their own were better at retrieving a hidden object that was to the *right of* or *left of* a prominent feature in a room than children who did not know these terms. Previous work by Hermer and Spelke (1994, 1996) suggested that younger children (18–24 months old) could not use a feature as a relational guide which might be construed to suggest the children could not encode the location of a hidden object as *right-of/left-of* because they lacked these specific terms in their vocabulary, further suggesting that language acquisition was a key factor. However, because the study was correlational, it is possible that a third factor correlated with language development was responsible for both the acquisition of the terms and improved performance in the orientation task. In a follow-up study, they found that adult performance was disrupted by a concurrent verbal shadowing task that blocked adults' *accessibility* to labels, strengthening their argument that language was the critical factor (Hermer-Vasquez, Spelke, & Katsnelson, 1999). Taken together, findings from these studies led the experimenters to conclude that labels served to bind together relevant information. Importantly, in both Hermer's and Gentner's studies, inaccurate or imprecise language did not improve performance – lending support to the idea that precise, accurate labels for spatial relations are necessary—a question that we also address in the current work. Alternatively, because adults were denied *access* to the appropriate verbal labels, these results also point to the possibility that it is *accessibility* to linguistic coding that drives performance. Taken together, the evidence indicates that language affects the ability to encode or remember, spatial relations and locations, but it is not clear whether having the term in their vocabulary (*acquisition*) is all that is needed or whether *accessibility* of the label – through priming or retrieval – is an additional required step.

Are precise, accurate labels necessary?

Given the existing evidence, it is not clear whether the precise, accurate term is necessary to aid relational judgments or if any label would do. Some studies found that only certain labels aid relational judgments. For example, recall that Loewenstein and Gentner (2005) found that children who were provided the precise, accurate label performed best in a retrieval task. In a similar vein, Shusterman, Lee, and Spelke (2011) found that preschoolers performed better in a reorientation task when they were supplied with linguistic cues pertaining to the precise object location ("I'm hiding it at the red wall") than when they were provided generic cues ("I'm hiding the sticker over here") or nonspatial cues ("Look at the pretty red wall"). Similarly, Dessalegn and Landau (2008) – who studied 4-year-olds' ability to remember a patterned square – found that children had difficulty remembering the specific red-green relation depicted in a square unless they were told the specific relation (e.g., "the red is on (*the left of*) the green") during the sample presentation – despite their inability to correctly label *right/left* relations outside of this task. Findings from studies like these suggest that the ability to make relational matches is supported by the use of the specific linguistic labels that denote relational concepts (Gentner, 2010; Gentner & Ratterman, 1991). However, Landau's work (see also Landau & Lakusta, 2009) additionally suggests that the effects of language may be transient, and thus are not always be found, particularly since the children studied by Dessalegn and Landau (2008) could not correctly label "right" or "left".

Opposing the idea that specific labels are necessary is evidence suggesting that words other than precise, accurate relational terms also promote relational judgments. Christie and Gentner (2013) found that providing 2- and 3-year-olds with a novel noun (e.g., *This is a truffet, can you find another truffet?*) improved their performance on a *same/different* relational match-to-sample task. In this task, children had to match shape relations depicted on cards; when trained on the labels *same* and *different*, only 3-year-olds improved in their performance; however, when a novel noun was applied to the card, both 2- and 3-year-olds made more relational choices. Christie and Gentner (2013) considered this finding as evidence that a novel noun "invites comparison" that "highlights the relational commonalities." Complementary evidence for the usefulness of other kinds of terms is provided by Son, Smith, Goldstone, and Leslie (2012) in their label-matching study with 4–5-year-olds. In their study, children were able to remember the relation shared by three objects (either a "sharing" or a "pulling" relation) both when novel and known labels were provided. That is, children generalized the named relations to new object sets when provided with novel terms (e.g., using the label Ko-Li-Ko to designate an ABA relation) or known terms (e.g., "pushing" or "pulling"). In short, some studies find that only the correct relational labels aid relational judgment whereas other studies suggest that other kinds of terms also aid performance. If applying *any* label helps relational processing, then it may be that language serves to anchor the relevant information when committing it to memory. In this case, the label might be helping to mark the information for later use and memory retrieval. This is a possibility which we explore in this paper.

Issues with previous findings

One reason that it is difficult to draw clear inferences from past studies is because of differences across tasks, relations, and the age groups tested. For example, Loewenstein and Gentner (2005) studied knowledge of vertical relations (e.g., *top*, *middle*, *bottom*) in 4-year-olds, and Hermer-Vazques et al. (2001) studied knowledge of horizontal relations (e.g., *right* and *left*) in 6- and 7-year-olds. Loewenstein and Gentner (2005) used a task in which children had to apply a mapping strategy while Hermer-Vazques et al. (2001) task required children to navigate inside a room. Both these tasks required a child to move his or her whole body as part of their response, which may be an added burden to the otherwise cognitive task. Although these studies need not contradict each other, it is more difficult to combine their findings into a cohesive story without evidence from a single study in which