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Plasticity of human spatial cognition: Spatial language and cognition covary across cultures

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ABSTRACT

The present paper explores cross-cultural variation in spatial cognition by comparing spatial reconstruction tasks by Dutch and Namibian elementary school children. These two communities differ in the way they predominantly express spatial relations in language. Four experiments investigate cognitive strategy preferences across different levels of task-complexity and instruction. Data show a correlation between dominant linguistic spatial frames of reference and performance patterns in non-linguistic spatial memory tasks. This correlation is shown to be stable across an increase of complexity in the spatial array. When instructed to use their respective non-habitual cognitive strategy, participants were not easily able to switch between strategies and their attempts to do so impaired their performance. These results indicate a difference not only in preference but also in competence and suggest that spatial language and non-linguistic preferences and competences in spatial cognition are systematically aligned across human populations.

1. Introduction

Questions about the plasticity of human cognition are central in cognitive science. How much individual variation is there in fundamental cognitive concepts and processes, and how much is this variation due to ontogenetic plasticity in human cognition? Given shared experiences within cultural groups but different sets of experiences between them, do we see population level differences in human cognition? Prominent in this context, is the issue of language differences and what they imply about possible differences in human conceptualization and expertise on a population level (Gentner & Goldin-Meadow, 2003; Levinson, 2003). There are around 7000 human natural languages and they differ in fundamental ways both in their form (sound systems, syntax) and their lexical inventories (the concepts coded in language) (Evans & Levinson, 2009).

The consequences of these linguistic coding differences have been hotly debated. One school of thought, following Fodor (1975), predicts little or no cognitive effects: there is a prelinguistic 'language of mind' that harbors all attainable human concepts, which a language selects from (Fodor, 1975; Gleitman & Papafragou, 2005; Pinker, 1994). Another line of thought claims that language gives rise to the concepts we use, or that at least the packaging can greatly facilitate mental processing (Dennet, 1991; Vygotsky, 1962), and make available cognitive adaptations to specific cultural environments (Levinson, 2003; Lucy, 1992). It may do this for example by 'coding' (Brown & Lenneberg, 1954), by 'recoding' (Miller, 1956), by providing relational concepts (Brown & Lenneberg, 1954; Gentner &

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Goldin-Meadow, 2003; Whorf, 1956). The resulting prediction of this latter perspective is that language differences imply cognitive differences.

Cross-linguistic variation provides a natural laboratory to test some of these different predictions. Even in just the last decade there has been considerable empirical work in a number of domains describing language-specific effects on cognition: for example color (Roberson, Davies, & Davidoff, 2000), number (Gordon, 2004; Pica, Lemer, Izard, & Dehaene, 2004), space (Haun, Rapold, Call, Janzen, & Levinson, 2006; Haun & Rapold, 2009; Levinson & Wilkins, 2006; Majid, Bowerman, Kita, Haun, & Levinson, 2004; Mishra & Dasen, 2005; Pederson et al., 1998) and time (Boroditsky, 2001). The conclusions vary across domains – for example, with respect to color (currently the best explored perceptual domain) recent results show on the one hand language-determined categories and linguistic effects on perceptual categories, and on the other universal constraints on color naming and language-independent category effects (see Regier and Kay (2009) for review).

The spatial domain has been intensively examined but has proved particularly controversial. It is incontrovertible that major cultural differences exist in the linguistic coding of space (Levinson, 2006; Pederson et al., 1998), and in the coding of major frames of reference in particular. Of special interest has been whether languages that primarily code different frames of reference would predict different non-linguistic spatial coding in their speakers. A considerable body of experimental evidence, based on cross-cultural comparison, suggests that the language one speaks indeed coincides with the frames of reference in which spatial memory and inference preferably operate (Haun & Rapold, 2009; Haun et al., 2006; Levinson, Kita, Haun, & Rasch, 2002; Mishra & Dasen, 2005; Pederson et al., 1998; Wassmann & Dasen, 1998). Nevertheless, doubt has been cast on these results from a number of different directions, both methodological and conceptual (Li, Abarbanell, & Papafragou, 2005; Li & Gleitman, 2002).

This paper attempts to resolve some of the issues in the spatial domain, along the following lines. First, we review the conceptual and methodological sticking points that have obstructed a clear consensus on the facts: (i) What are the relevant frame of reference distinctions, and how can we experimentally distinguish their use? (ii) Are the findings indicative of *preference* for one frame of reference, or about *ability* to operate in different frames of reference? (iii) How sensitive are the results to instructions that push either preference or ability? (iv) How sensitive are the results to task complexity, for example, does greater task complexity induce a reversion to a non-cultural, innate preference? (v) How can we control for orthogonal differences in subject populations and testing conditions?

Second, we report a series of experiments that were designed to address these issues by attending to each of these points. Here we first discuss the issues one by one, and explain how the experiments were designed to focus on them.

1.1. Frames of reference distinctions

Underlying linguistic descriptions of spatial arrays are coordinate systems or frames of reference (FoR). They serve to specify the directional relationship between objects, in reference to a shared spatial anchor (Levelt, 1984; Talmy, 1983). Extensive field research in over 20 languages, analyzing natural and elicited conversation, has revealed a threefold distinction between frames of reference encoded in language (Levinson, 2003), as illustrated in Fig. 1: (i) *Relative frame of reference:* a ternary, viewpoint-dependent FoR, with terms like front, back, left and right: "The ball is to the left of the tree (from my point of view)". In most European languages, this is the predominant frame in which people talk about locations and directions. (ii) *Intrinsic frame of reference*: a binary, viewpoint-independent relation, which specifies directions from a named facet of a reference object ("The garden is at the back of the building"). This is the main secondary frame in European languages, but in some languages (e.g. Mopan) it is the primary frame. These two FoRs are not always distinguishable in every utterance. Note the ambiguity of e.g. "The cat is in front of the truck" – on the intrinsic reading it is at the facet we call the front, on the relative reading it is between the speaker and the truck, and thus can be at its side. (iii) *Absolute frame of reference*: a binary relation between a reference object and a landmark using a system of fixed angles (e.g. north/south/east/west), as in "The lake is north of the town". This system is used in European languages normally only for geographic scale locations and directions, not e.g. for describing the location of things on a table – but many languages use it as the main FoR on all scales.

It is not a trivial task to map these linguistic distinction to related cognitive systems and previous attempts have resulted in much confusion (Levinson et al., 2002; Li &

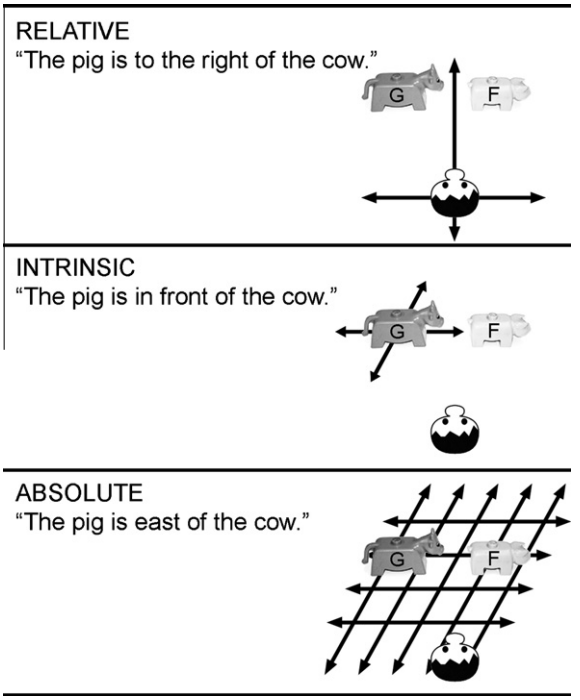

Fig. 1. Distinctions between three linguistic frames of reference.