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Spatial cognition in apes and humans

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The debate on whether language influences cognition is sometimes seen as a simple dichotomy: cognitive development is governed either by innate predispositions or by influences of language and culture. In two recent papers on spatial cognition, Haun and colleagues break new ground in bringing together a comparative cognition approach with a cross-linguistic framework to arrive at a third position: that humans begin with the same spatial reference frames as our near relatives, the great apes, and diverge later owing to the influence of language and culture.

Introduction
In two recent papers [1,2], Haun and colleagues unite two important current lines of research: cross-linguistic studies of language and cognition [3], and studies in the comparative cognition of humans and great apes [4,5].

This research draws on a large-scale investigation of cross-linguistic differences in spatial semantics [6,7] that has identified three frames of reference that speakers use to identify the location of an object. The egocentric (or relative) frame describes the location of an object relative to the speaker, as in 'the chair on my left'. The object-centered (or intrinsic) frame describes locations relative to a landmark object, as in 'the chair in front of the fireplace'. Finally, the geocentric (or absolute) frame describes locations relative to a global frame, as in 'the chair in the northwest corner'. Languages can use more than one of these frames, but in many cases one frame is dominant. In particular, the egocentric frame is dominant in English, Dutch and German, whereas the geocentric frame is dominant in Tzeltal (southern Mexico) and Hai||om (Namibia), among others. Using a clever set of tasks, researchers have amassed evidence that people given nonlinguistic spatial tasks show a strong tendency to use whichever frame is dominant in their language [3,6] (but see Ref. [8]). This work has been a major impetus in reviving the Whorfian question of whether the language we speak influences the way we habitually think [9–11].

Evidence of linguistic effects on spatial cognition invites the question of how they develop. Do we begin life with natural proclivities or instead with 'blank slates' on which language, culture and other experience impose spatial frames? Haun *et al.* addressed this question in a bold and ingenious set of studies that combines cross-linguistic developmental comparisons with cross-species comparisons between humans and our close relatives, the great apes.

Spatial frame of reference
Haun *et al.* [1] compared Dutch and German speakers, whose language (like English) primarily uses an egocentric frame of reference, with speakers of Hai||om (a Khoisan language spoken in Namibia), which primarily uses a geocentric frame. They used a hide-and-search task with the five-object arrays shown in Figure 1. The subject (S) watched the experimenter hide Target 1 under one of the five identical objects on Table 1, then moved to Table 2 (now facing the opposite direction) and searched for Target 2. The location of Target 2 was determined by one of three rules, corresponding to the three spatial frames. For example, if Target 1 was in the northwest corner of Table 1 (and directly left of S) then, in the geocentric condition,

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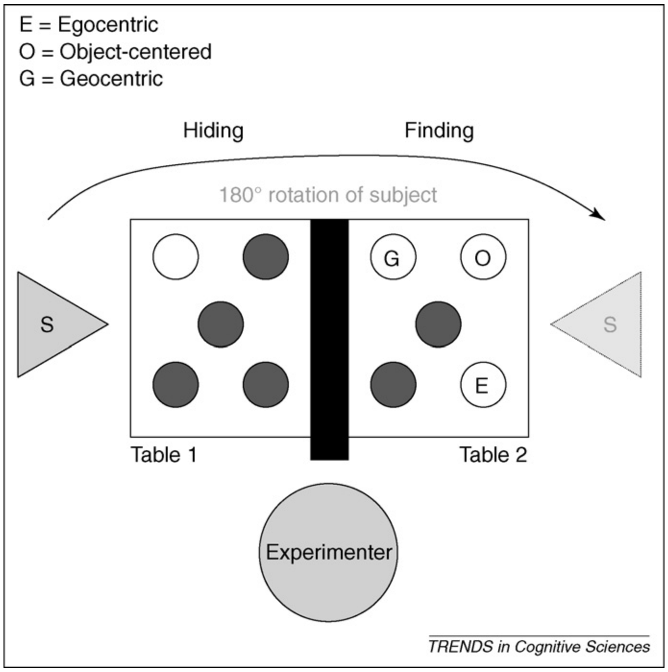

Figure 1. Experimental setup for an example trial in Ref. [1] (Experiment 1). Ten identical cups were placed on two tables (five cups on each table). Participants watched while a target was hidden under the cup depicted as white (Hiding). Then participants moved to the other table and indicated where they thought a second target was hidden (Finding).

Target 2 would be in the northwest corner of Table 2; in the egocentric condition, it would be directly left of S, and so on. Subjects received ten consecutive trials with each of the three rules.

The results showed marked differences between the two language groups. Dutch-speaking adults and eight-year-olds were most accurate in the egocentric condition, whereas Hai||om speakers of both ages were most accurate in the geocentric condition. In short, by eight years of age, people show the cognitive bias that is consistent with their language.

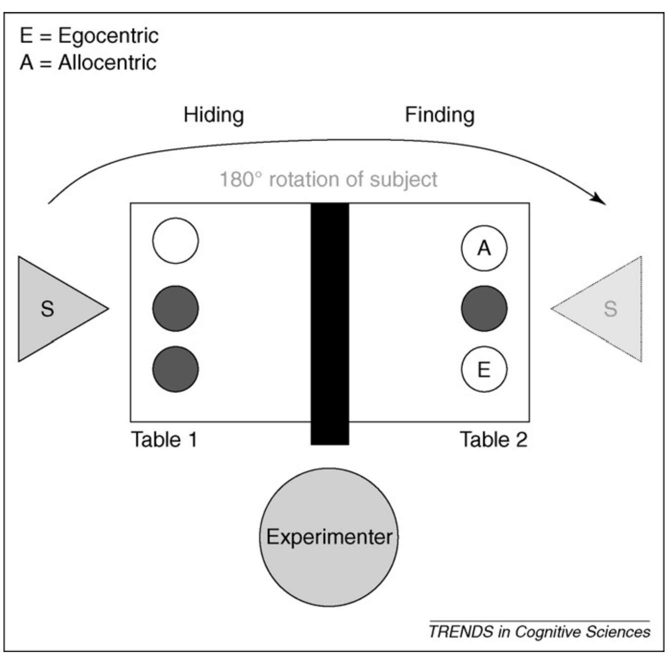

Figure 2. Experimental setup for an example trial in Ref. [1] (Experiment 2). Six identical cups were placed on two tables (three cups on each table). Participants watched while a target was hidden under the cup depicted as white (Hiding). Then participants moved to the other table and indicated where they thought a second target was hidden (Finding).

Haun *et al.* [1] next compared younger children with great apes on a similar (but simpler) frame-of-reference task, using a three-object array (Figure 2). They tested four-year-old German children and great apes (gorillas, orangutans, chimpanzees and bonobos, which did not differ significantly among themselves on any of these tasks). Subjects received ten trials in each of two conditions: egocentric or allocentric (where allocentric includes both geocentric and object-centered, which cannot be distinguished using this simple array; Figure 2).

Both great apes and four-year-old German children were substantially more accurate in the allocentric condition than in the egocentric condition. (This finding will surprise those who believe that egocentrism characterizes the preschool years, but it is consistent with evidence of early use of allocentric frames [12].) Given this early common bias, the fact that eight-year-olds performed best on the frame favored by their language is strong evidence for effects of language on the way we most readily conceptualize space. (Although the authors are careful to note that culture or environment could be the causal factors, a thorough review of frame-of-reference studies across languages [6] suggests that the dominant factor is language.) Developmentally, we seem to see an early allocentric bias that is shared with our great ape cousins, which gives way by late childhood to the bias that is inherent in the language we speak – egocentric for Dutch (and German and English) and geocentric for the Hai||om.

The results also show that entrainment into a preferred frame is not absolute: for example, Dutch speakers could learn the non-preferred geocentric rule to some extent. This is an important point – human cognition is pluralistic: we can typically encode the same external scene in many ways. Indeed, human adults [8] and infants [12], and even rats [13], can adopt different frames of reference according to the task and context. The neo-Whorfian debate should not be on whether language forces one unique conceptual system on its speakers but on whether it privileges some systems over others.

Encoding location versus features

In another study, Haun *et al.* [2] looked earlier in development at a different aspect of spatial cognition: do subjects track the location of a hidden object by its spatial location or by the features of its hiding place? They used a switch task – a kind of shell game but using distinctive 'shells' (inverted containers). A target was hidden under one container; then two containers were swapped while the display was occluded. Three-year-olds searched under the original container (in a new location), but apes and one-year-olds searched in the same location (under a different container). Thus, infants initially track by location rather than by object features, as also found in Ref. [14], and we share this initial location bias with apes.

This is a fascinating result, but it raises many questions. First, are apes and human infants really doing the same thing? This task does not distinguish among frames of reference, so apes could be encoding geocentrically and infants egocentrically, for example. Second, what causes the shift to searching by object features at three years of age? Haun *et al.* speculate that noun learning fosters attention to objects [15], an intriguing (and testable) possibility.

Concluding remarks

Putting the two studies together, in one task [2], humans share a locational bias with apes at one year of age, but diverge to an object bias by three years. In the other [1], we share an allocentric bias with apes at four years and then diverge to an egocentric bias (or not) by eight years, according to language and culture. This suggests that different aspects of human acculturation influence different spatial representations and processes. For example, the early divergence of humans from apes could be related to different experiences with objects [16]. Fans of language effects might speculate that noun learning drives the early shift from coding by location to coding by object features and that the learning and entrenchment of relational terms (which occurs later [17]) drives the shift from an allocentric to a language-consistent bias in frame of reference. These questions will be fascinating to pursue.

There is a grand vision here: that of tracing spatial cognition from its shared primate substrate through to the effects of symbolic systems. The research of Haun and colleagues [1,2] offers a deeper perspective on how our initial predispositions interact with language and culture in human development.

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Letters

Integrating simulation and theory of mind: from self to social cognition

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Investigations of brain substrates for social cognition have polarized in two camps. The simulation camp focuses on so-called shared circuits (SCs) that are involved in one's own actions, sensations and emotions and in perceiving those of others [1,2]. The theory of mind (ToM) camp emphasizes the role of midline structures in mentalizing about the states of others [3]. Scientific energy has often flown into fruitless arguments about which camp is closer to the truth [4], but the true questions for contemporary social neuroscience should be (i) why do investigators find different sets of areas to be most prominent, and (ii) how do the two sets of brain areas interact? Here we propose a highly speculative model that complements the view of Uddin *et al.* [5] to stimulate and canalize future empirical work into a direction we believe to be promising.

Social cognitions range from the intuitive examples studied by simulationists to the reflective ones used by ToM investigators. Witnessing someone drink a glass of milk with a face contracting in an expression of disgust is an example at the intuitive extreme of this continuum. In such cases, premotor and parietal areas for actions [6], the insula for emotions [7,8] and SII [9] for sensations form SCs that translate the bodily states of others into

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