Culture & Psychology

http://cap.sagepub.com

Geocentric Dead Reckoning in Sanskrit- and Hindi-Medium School Children

Ramesh C. Mishra, Sunita Singh and Pierre R. Dasen

Culture Psychology 2009; 15; 386
DOI: 10.1177/1354067X09343330

Article

Abstract A linguistic and cognitive process that has received scant attention in mainstream developmental psychology is the use of a geocentric frame of spatial reference, which amounts to using a large-scale orientation system (such as cardinal directions) in describing and encoding the location of objects on table space, inside a room. As part of a larger cross-cultural study of the development of this process, in India, Indonesia and Nepal, we present here a study on the possible implications of using a geocentric frame of reference in developing an accurate dead-reckoning skill. Children aged 11 to 15 years in two types of schools in Varanasi, India, who were known from a pretest to use a geocentric frame in language and cognition, were blindfolded, spun around and led blindfolded to a second room. A majority of them were able to keep track of cardinal directions despite these disorienting procedures. They were interviewed about the processes and sources of their skill.

Key Words cross-cultural human development, geocentric dead reckoning, Hindu religious practices, orientation systems, Sanskrit schools, spatial language and cognition

Ramesh C. Mishra and Sunita Singh
Banaras Hindu University, India
Pierre R. Dasen
University of Geneva

Geocentric Dead Reckoning in Sanskrit- and Hindi-Medium School Children

Directed movements in space seem to be essential for the survival of almost all living creatures in the world. Human beings engage in a number of activities that involve the use of spatial information to organize their movements in order to reach desired goals. The kind of information they use, and the manner in which they are able to do so, have been the subject of debates among developmental psychologists for a long time. Piaget believed that children's sensori-motor experiences resulting from their interaction with the world in early years of life led to an increase in their spatial competence. While Piaget's theory has been widely used in research on spatial cognitive development

Culture & Psychology Copyright © 2009 SAGE Publications
(*Los Angeles, London, New Delhi and Singapore*) http://cap.sagepub.com
Vol. 15(3): 386–408 [DOI: 10.1177/1354067X09343330]

with considerable empirical support, some research grounded in strong nativist theory suggests that even infants are equipped with specific knowledge of their spatial environment (Spelke & Newport, 1998), indicating that the origin of spatial competence is not linked to sensory or motor experiences.

Whether our spatial knowledge is inborn or acquired through interaction with the world, research clearly suggests that the organization of spatial knowledge and its representation among human beings is very different from that of other species. Human beings' capability of engaging in complex internal processes allows them to represent the spatial world from various perspectives and understand the objects undergoing rotational transformations. Hegarty (2004) indicates that these symbolic abilities allow us to communicate about our spatial environment in a flexible manner, and to carry out many mechanical activities in thought (e.g. reasoning about the functions of gears or pulleys). While the notion of internal representations is essential for some authors (e.g. Huttenlocher, 2005), others (e.g. Brooks, 1991; Thelen & Smith, 1994; Warren, 2005) raise questions about its scientific necessity and advise to do away with it entirely. The argument is that in understanding behavior, the notion of representation introduces certain mysterious and unobservable entities which explain nothing, and whose existence is difficult to demonstrate empirically.

Research by Piaget and Inhelder (1948/1967) suggests that spatial knowledge in adults is accurate, metric and well structured, involving a Euclidean system of spatial representation. As a result, adults can easily remember and reconstruct spatial layouts, take another person's perspective, use spatial representations based on a coordinate system and perform a variety of spatial tasks that appear to be difficult for children. Although such a characterization of adult spatial thought has been questioned in recent years (see Newcombe & Huttenlocher, 2006), it still appears quite useful in view of its parallels discovered in cognitive (Taylor & Tversky, 1996) and linguistic (Levinson, 2003) traditions of research on the organization of spatial knowledge in human beings.

Research indicates that in organizing their spatial knowledge, individuals use certain frames of reference. Spatial frames of reference are a means of representing the location of entities in space (Klatzky, 1998). They help us in transforming and using spatial information about the world to achieve a variety of goals, including the navigation of the world and its description to others. Piaget's theory postulates the use of topological, projective and Euclidean frames of reference in the course of spatial concept development. Taylor and Tversky (1996) refer to object-centered, viewer-centered and environment-centered frames of spatial reference, which closely correspond to Piaget's proposition. In linguistic research, Levinson (2003) makes a distinction among intrinsic (I), relative (R) or egocentric, and absolute (A) or geocentric frames of reference (see Levinson, 2003, p. 40). In an intrinsic frame, the objects are defined in relation to each other, whereas in a relative frame they are defined in relation to the viewer's position (e.g. the man is to the left of the house). In an absolute frame, the objects are defined with reference to wider dimensions such as cardinal directions (e.g. the man is north of the house). It is also indicated that different languages are characterized by the availability and preferential use of these different frames of reference. For example, Tzeltal (a Mayan language) is characterized by the presence of A and I (but no R), with a preference for the use of A. On the other hand, European languages such as English, Dutch or French have all three frames available, but there is a distinct preference for the R frame; geocentric references are used only for travel, and are never used for small-scale spatial layouts. Tamil (an Indian language) is characterized by the existence of all three frames of reference (i.e, A, I, R), but the preference is for the use of R in urban populations, and for the use of A in rural populations (Levinson, 2003, p. 182; Pederson, 1993).

The preferential use of a particular frame of reference in a language community indicates that there must be some ecological, cultural or social normative conditions to encourage the use of one reference frame over others. Studies carried out in India and Nepal (Dasen, Mishra, Niraula, & Wassmann, 2006; Mishra, Dasen & Niraula, 2003; Mishra & Dasen, 2005; Niraula, Mishra & Dasen, 2004) indicate that the choice of a particular frame of reference in language or cognition is encouraged by ecological conditions and is reinforced by cultural practices of the given populations. For example, in rural Nepal, where the obvious reference point is the Himalayas, places and objects are generally described and encoded in absolute terms with reference to 'up' and 'down' (Nepali terms *unbho* and *undho* to refer to mountain and valley, respectively). In Indian villages of the Gangetic plains, where such obvious reference points (as the Himalayas) do not exist at all, people predominantly use an absolute frame with reference to cardinal directions (e.g. North, South, East, West), often supported by some obvious local landmarks known to everyone (e.g. temple, road or pond). In urban settings, such as the city of Varanasi, where the use of left–right is more functional in terms of moving through streets and alleys, the egocentric frame of reference (mainly left, right) is used in combination with the geocentric one.

A person using the geocentric frame is able to carry the large-scale dimensions of space even into small-scale environments (e.g. inside a building or room), and apply them with reference to objects even on a table top (Mishra & Dasen, 2005; Mishra et al., 2003). The ability to do so requires constant updating of one's position according to cardinal directions during movements in familiar or unfamiliar places. Thus, holding cardinal directions in mind during movements and judging one's position in relation to them at all times appears to be relevant to a geocentric frame of orientation. The process through which people constantly but unconsciously update their spatial position in the environment is called 'dead reckoning'. This process differs from that of 'tracking', in which people consciously engage in computations while walking in an unfamiliar space on the basis of visual information. In this process, each movement seems to be consciously attended, counted and linked to the final position.

Egocentric and Geocentric Dead Reckoning

Centuries ago when explorers like Columbus sailed through the Atlantic in search of the New World, they managed navigation through the open sea without the help of the navigational technology that is available to us today. They managed to do so by a process called 'dead reckoning'. Given an initial course, the navigator continually integrates his estimates of speed and deviations from that course, in order to guess at the current location. Historical records show that Columbus's guesses were often way off reality. Very sophisticated traditional navigation techniques were also devised by Micronesian navigators (Gladwin, 1970; Hutchins, 1983), who used a 'stellar compass' based on the observed rise and fall of stars. They kept track of their course by imagining the movement of a virtual island in relation to this compass. Despite its level of abstraction and precision, this scheme was based on dead reckoning, meaning that the navigator had to keep constant track of a multitude of factors. He could never go to sleep, because then he could not communicate the vast number of inputs to a shipmate.

The psychological processes in navigational schemes have been subjected to some laboratory research in recent years. For example, in an experimental study, Simmering and Spencer (2007) tested the ability of subjects to remember the location of a stimulus relative to some visible dots and then in the absence of those dots. It was found that in the latter condition, the subjects behaved as if the dots had never been there, but when interviewed, they indicated that they were able to impose the dots mentally, and they over-estimated their mental ability to do so. The researchers used these findings to support the notion of 'embodied cognition', which implies that people do have abstract abilities, but those abilities are fundamentally connected to their sensory experiences of the real world. Based on this experiment they argued that all navigation involves reliance on certain perceptual cues, and claimed that even Micronesian navigators must rely on sensory cues derived from the motion of their body for successful navigation. However, it may be noted that their study neither probed into actual dead reckoning, nor did it focus on the processes involved in the navigation skill that develops over a long period of time in the face of several risks and challenges at sea.

In contrast to the claim for a physical cue-based navigation process, some research shows that a person's movement on the ground is represented cognitively like a survey of the territory as seen from above. This may happen more often when people cannot see the environment while walking (e.g. in a blindfold condition). In such situations, they may be preoccupied with representing their internal sensations of movement with reference to a mental map. In a theoretical paper, Rieser (1999) argues that these imagined events serve as powerful frames of reference to draw inferences about one's own location, or the location of other objects, or landmarks in space.

Greidanus (2002) blindfolded university students and led them along a path in an unfamiliar suburban neighborhood, while another group followed the same path without a blindfold. During the walk, the blindfold was removed periodically and the students were asked to choose a line drawing that best represented an overhead view of their trajectory. Blindfolded students chose the representation of the path with 29% accuracy, while sighted students did it with 43% accuracy. All students generally spent some time to eliminate the wrong path drawings using their memories of particular path segments and turns. It was also noted that students whose vision was restricted to the views of the path within one meter of their feet performed as well as did the sighted subjects. Accurate encoding of movements in this case was considered to indicate the importance of optic flow, since the students were not able to see the landmarks that might be useful at the point where they had to identify the configuration of their paths.

Dead reckoning as a process of understanding one's position in space has also drawn some interest in studies that focus on memories of travel. In these cases, sensation of movement needs to be monitored for long periods without calibration against known landmarks. According to Burch (1986), dead reckoning requires the navigator not only to be able to calculate speed, time and direction of travel, but also to estimate the error associated with each of these. The latter is especially important, because navigation by dead reckoning is inherently error-prone, and hence it requires appropriate recalibration. Estimates of positional error guide the navigator to determine the point when other means are necessary to fix a location, or when other heuristics must be used in order to reach the goal. Viewed from this perspective, dead-reckoning skill consists not only of procedural expertise, but also of judgment concerning errors (Cornell & Heth, 2004). In some situations these errors may be quite problematic. For example, in sea navigation, error of a single degree will take the navigator far from the target because the small deviation will become large with distance.

Closely related to the process of dead reckoning is 'path integration'. Mittelstaedt and Mittelstaedt (1982) suggest that it is possible to compute a location by integrating 'directed velocity' over time. A navigator may sense it by several means, such as the flow of visual patterns, the feel of the wind, the fading of sounds or other means. When the information is derived from the internal sensation of movements (i.e. proprioception), the process is called *'inertial path integration'*. When the information comes from the changes in the flow of external events (e.g. textures), the process is called '*noninertial path integration*'. A key feature of path integration is that calibration in relation to external landmarks does not occur continuously, but after significant events along a path. In dead reckoning also, although calibration usually occurs at significant path nodes, the process is retrospective in nature, implying certain processes that depend on representations of previous segments of the path. Cornell and Heth (2004) point out that, since people produce organized memories of their travel, human navigation seems to fit with the models of dead reckoning.

In most descriptions of dead reckoning or 'inertial navigation' (e.g. Newcombe & Huttenlocher, 2006), one gets the impression that it is necessarily an egocentric process based on tracking of one's own body movements and their deviation from an initially set position. However, this may be an ethnocentric bias, all studies being carried out with speakers of European languages. Similarly, when Klatzky (1998) concludes that 'on the whole, the literature is suggestive of a more accurate representation of egocentric parameters than allocentric parameters' (p. 9), she does not take into account the fact that the literature she reviewed is entirely Euro-American.

However, some evidence suggests that dead reckoning can be carried on in a geocentric manner in which the representations are not linked to body movements. Many people can carry geocentric references wherever they go, and can relate to them in all situations. Support for this can be derived from some informal studies (see Levinson, 2003) in which people were transported to unfamiliar locations, made to walk through bushes or stay in a room without windows, and asked to point to near and far-away locations. The accuracy of their pointing was analyzed in terms of their deviations from the point of reference. The findings revealed that if the participants were predominantly absolute (geocentric) language speakers, their judgments of direction and distance were remarkably accurate in all situations. In fact, the Guugu Yimithirr and Hai//om samples (both absolute language speakers, respectively Australian Aborigines and Kalahari San) were even more accurate than homing pigeons, while Dutch and English subjects, even though experienced (called 'woodsy'), were notoriously poor.

According to Levinson (2003), these findings suggest that absolute language speakers 'have in constant play a rather precise mental dead reckoning system', and that 'absolute language speakers are much better dead reckoners than our "relative" language speakers' (p. 241).

> In order to speak a language that encodes angles on the horizontal in absolute coordinates, an individual will need to be constantly oriented (know where the local 'North' or 'South' is), and moreover will need to know where he or she is with respect to other places that may need to be referred to. The system can never go 'on holiday', since one never knows what experiences or directions one may need to talk about. Such languages, I have argued, *force* dead reckoning on a more or less constant basis. Speaking such a language is thus a *sufficient*, although not necessary, condition of being a good dead reckoner. (p. 243)

While Levinson suggests the possibility of strong dead reckoning among absolute language speakers, he also warns against considering these findings 'to hold up worldwide', and searching for a 'direct causal connection between dead reckoning abilities and language' (p. 241). He indicates that no simple ecological explanation of dead reckoning is likely to succeed, but that 'finer-grained cultural factors may indeed be closely correlated with good dead reckoning skills' (p. 243).

Cottereau-Reiss (1999) carried out a study with 80 Paicî Kanak children, aged 4 to 16 years (and 20 adults), on the East Coast of New Caledonia. The orientation system in New Caledonia is a variant of the well-known Oceanic systems with two axes expressed as up/down, one along the coast and the other one inland/to the sea. Names of localities are also frequently used. Cottereau-Reiss used a blindfold situation for language elicitation with a few children. Children played this game in groups of three: one was blindfolded and the two others had to guide him or her to find an object placed somewhere in the room. They were not allowed to move themselves during this procedure. What happened is that the two guides used exocentric language (notably up and to the sea, and conventional or situational landmarks) as if their blindfolded peer could actually see. There is anecdotal evidence (P. Cottereau-Reiss, personal communication, 1999) that the children could actually follow these directions despite being blindfolded, which implies that they could keep track of their movements within a space for which they must have kept a largely exocentric representation.

In her detailed study of Marquesan spatial language, Cablitz (2006) included a section on children's learning of the local geocentric spatial system. She found that, while even very young children could use the system accurately in familiar surroundings, they could not do so when taken to an unfamiliar setting.

The purpose of our study is also to understand how children who encode spatial arrays predominantly in a geocentric frame carry directional information to other places with them. In other words, the study attempts to find out how well a group of children who predominantly use a geocentric frame can keep track of orientation inside a house, even under reduced environmental cues, and to document how they do it.

Dead reckoning inside of a building is of course quite different from navigation in open spaces, because it involves keeping track of mainly 90° turns. In this, one can see the advantage of having a geocentric spatial representation, which allows one to map these turns onto a grid with 90° angles, in case of cardinal directions, or even 45° angles, if there are 10 named directions (8 with precise angles) instead of 4. The latter is the case in the Sanskrit spatial cosmology that is described in the next section.

Sanskrit Spatial Cosmology

The spatial cosmology that regulates the upbringing of a child born in a Hindu family in India, but more so of a child who is admitted to a Sanskrit-medium school at an early age, is unique in many respects. A precise description of spatial language in Sanskrit literature is found in the *Rig Veda*, which is an important and the oldest Hindu religious scripture. The hymns of the *Rig Veda* are composed in praise of deities like fire, wind, water, sun, moon, and so on. These were originally conceived of as forces presiding over natural phenomena. Among them, the sun (*surya*) is regarded as the soul of all living beings.

The verses of the *Rig Veda* hold various gods responsible for producing an order in space, with the sun as its supreme lord. While all divisions of time and space are based on the sun, other deities are conceptualized to occupy different directions forming a circular structure, called the *surya mandal*. In Sanskrit literature, we find the division of space in 10 segments, each defining a particular direction. These directions are named as *uttar* (North), *dakshin* (South), *purva* (East), *pashchim* (West), *ishan* (North-East), *agneya* (South-East), *vayavya* (North-West), *nairitya* (South-West), *urdhva* (up) and *adhar* (down). The mental representation or cognitive map of space is guided by this particular scheme, which plays an important role in determining one's location in the world. People who are socialized in this 'worldview' from their early years are likely to resolve their 'spatial world' in a manner that may have some important consequences for the understanding of their position in and relationship with the outside space.

An important proposition of the Indian philosophical tradition is that a viewer's perspective to resolve the spatial world can represent the same world in different manners with multiple modalities and frames of reference, which may eventually produce different kinds of spatial knowledge. Thus, children can be expected to experience and construct space in different ways depending on the perspectives shared by the people with whom they interact in the course of development. Mishra and Vajpayee (2008) have described the context of Sanskrit-medium schooling in India, the life and salient experiences of children attending those schools, and their impact on the psychological functioning of children. It is indicated that the nature of experiences of Sanskrit school children, both in family and in school, their patterns of interaction with peers and teachers, and their involvement in religious and cultural practices through daily routines (in which spatial knowledge forms an integral component) are likely to promote their relationship with and understanding of space in a strong geocentric manner.

Vajpayee, Dasen and Mishra (2008) compared 376 10- to 14-year-old Sanskrit- and Hindi-medium school children with respect to their knowledge of cardinal directions as well as their use of language, and encoding on spatial cognitive tasks. The findings revealed that about 87% of the Sanskrit school children had, as expected from their experience and training, a perfect knowledge of the NSEW orientation system as against 43% of the Hindi-medium school children, both outside and inside a room. Not only that, they were also more correct in their knowledge of right, left, front and back (RLFB) than

Hindi-medium school children. With respect to language use, the analysis indicated that Sanskrit school children used spontaneously more (correct) geocentric language than Hindi-medium school children on language elicitation tasks. On spatial memory tasks designed to indicate which spatial frame of reference is used non-verbally, the Sanskrit school children used a larger proportion of geocentric responses than Hindi-medium school children. The findings also indicated that those who used a geocentric frame of reference performed better on tests measuring general spatial cognitive abilities (e.g. the Kohs Block Designs Test).

Sample and Design

The study, which is part of a larger research program, was carried out in the city of Varanasi (India) with Sanskrit-medium and Hindi-medium school children of 11–15 years of age. The sample consisted of 24 Sanskrit- and 27 Hindi-medium school children. While the Sanskrit school sample consisted of boys only, the Hindi school sample comprised 25 girls and 2 boys. They were known from our main study to use mainly a geocentric frame of reference in language and cognition. In particular, the selected children knew all cardinal directions not only outside in open space, but inside the room in which they were tested.

We had initially intended to include a sample of children from the Hindi-medium school who used predominantly egocentric language and encoding, but this proved to be difficult, because these children failed systematically our procedure, and were extremely frustrated. Hence the study does not include such a control group.

Procedure

Children were taken individually to an unfamiliar room without windows on their school compound. They were asked to indicate the four cardinal directions (i.e. East, West, North and South), first with eyes open, then after being blindfold and spun around (three and a quarter times, so that they did not face the initial direction). The responses were recorded. Then they were walked to another room with the blindfold on. The movement between the two places required several turns. In the new room, they were again spun around (three and a quarter times) and asked again to tell the four cardinal directions (eyes still blindfold). The responses were recorded. While spinning on both occasions, care was taken that (1) the children did not face the same direction they were facing prior to spinning, and (2) while spinning children and asking about directions, the researcher did not stand at the same point.

Then (blindfold removed), the children were given a 'route description' task in order to check on their use of geocentric or egocentric language. A pathway was laid out on the ground, which consisted of several segments with right-angle turns set out along the main cardinal directions, and also one diagonal and circular turn (for more details, see Mishra & Dasen, 2005). The experimenter was blindfolded, and the children had to guide her verbally along the path. The directions given by the children were recorded.

Immediately after this procedure, the children were interviewed (in Hindi) with the help of a 22-item questionnaire. It focused mainly on how children had kept track of directions during the blindfold experiment, as well as how they acquired the knowledge of directions, how they carried it with them, and how they were able to use their knowledge in new and unfamiliar places and situations where no external cues are available.

Analysis and Results

The initial analysis focused on the accuracy of children's responses pertaining to cardinal directions in different test situations. Using the degree of accuracy of directions, children were categorized as 'level 1 experts' (all directions correct with open eyes, but not with blindfold, nor in the second room), 'level 2 experts' (all directions correct with open eyes and blindfold, but not in the second room) and 'level 3 experts' (all directions correct in all three situations). The distribution of different levels of experts in the two types of schools is given in Table 1.

The overall performance of these children indicated that 56% of them could tell cardinal directions with perfect accuracy, despite being blindfolded, turned around and led to another room, and another 26% could do it blindfolded in the first room. A significant difference in the level of expertise between the Sanskrit and Hindi school children was noted (Chi-square = 6.97, $p < .01$), although both groups were mainly geocentric in their language and encoding.

Table 1. Distribution of different levels of experts in Sanskrit and Hindi schools

	Level 1 experts	Level 2 experts	Level 3 experts	Total
Sanskrit	2	4	18	23
Hindi	7	10	10	27
Total	9	14	28	51

Sanskrit and Hindi school children were interviewed about the strategies they used in holding on to directions in the blindfold condition. Since there were only two 'level 1 experts' in the Sanskrit school, we decided to combine levels 1 and 2 for this group. The results are presented in Table 2.

In the table we have organized the findings of the interview on the basis of four important features: process of knowing, basis of awareness, sources of knowledge and salience of directions in daily life. The analysis revealed a number of similarities and differences both within and across the school groups.

Process

One process of interest mentioned by many Sanskrit school children and some of the Level 3 experts in the Hindi school, was '*andaaz*', which indicates a process of making fine judgments based on habitual experience of the given situation. Since the process is brought into use in day-to-day life, it functions almost in an automatic manner. The children, who used '*andaaz*' seemed to 'just know' the directions:

Table 2. Interviews on processes in keeping track of directions in Sanskrit and Hindi school children with varying degrees of expertise: percentage of children giving various categories of answers

	Sanskrit school		Hindi school		
Levels of expertise	Level 3 (N = 18)	Levels 2 + 1 (N = 6)	Level 3 (N = 10)	Level 2 (N = 10)	Level 1 (N = 7)
Process					
'*Andaaz*' (reckoning)	50	67	30	0	0
Tracking	61	17	70	30	43
Movement of body	72	100	30	30	14
Prior knowledge	28	17	40	60	29
Awareness					
Sun	44	83	90	100	100
Other	28	17	10	0	0
Sources of knowledge					
Teacher	50	83	20	30	0
Mother	33	33	80	70	57
Father	67	50	80	50	86
Brother/Sister	22	0	10	0	0
Books	28	0	0	0	0
Experiences	28	0	0	0	0
Salience of directions in daily life					
Eating	100	100	60	60	43
Sleeping	72	100	70	80	43
Worshipping	94	100	70	90	57

they did not have to make any special efforts for it. This also means that, in fact, they find it difficult to provide much detailed introspection into how they have managed to succeed. Some children expressed this general, rather undifferentiated process as 'prior knowledge': they already knew and remembered the directions.

But most of the children, and in particular level 3 experts, do analyze the processes they use in some more detail. They say that they do some 'tracking' that involves some sort of computation while walking or being spun around. Attending to each movement (e.g. counting complete turns) and linking it to the final position is a chief feature of this process. Close to this is the category of 'body movements', referring most directly to proprioceptive cues. During the circular movements when being spun around, our body provides us with a valuable source of information.

Basis of awareness about directions

When asked, 'How did you know that East was that side?', most children indicated the 'sun' as the primary source of awareness of East and hence other directions. Since the source of light was not perceptible in the room without windows, and even more so when blindfolded, this either means that they took this cue ahead of time, before entering the building, or just that this is what is usually done under normal circumstances. Some level 3 experts in the Sanskrit school tended to say that they relied on other means, like the use of locally salient environmental cues (e.g. sounds), illustrating the fact that using the sun was not in fact possible with our procedure.

Sources of directional knowledge

When asked, 'How did you get knowledge about directions?', children indicated a number of persons who served as sources or agents of knowledge. This indicates that the knowledge of cardinal directions is indeed an important part of overt socialization, both in the family and at school. Sanskrit school pupils indicated 'teachers' more often than did Hindi school pupils, which is in line with that school's curriculum. The mother and especially the father are important sources of knowledge, indicating that this socialization occurs both at home and at school. Books and personal experiences also served as sources to shape the knowledge of directions for some Sanskrit school level 3 experts.

Salience of directions in daily life

With regard to the salience of directions in daily life, the findings suggest that knowledge of directions is somewhat more common for

Sanskrit than Hindi school children for organizing activities like eating, worshipping and sleeping (particularly to avoid facing South). We have already examined the importance of cardinal directions in the life of Sanskrit school children, which is again confirmed from the interview data.

Beyond the categories listed in Table 2, some other striking differences between Sanskrit and Hindi school children were evident in the interview. When asked, 'If you were taken to an unknown place, would you be able to find out directions the way you have done here?', a majority of Hindi school children answered 'yes', indicating that they were quite confident of doing so. In the Sanskrit school the number of children showing confidence in the transfer of their knowledge was relatively smaller. On the other hand, when children were asked, 'Will you be able to find out directions in a dark night?', not a single child in the Hindi school indicated being able to do so, whereas in the Sanskrit school, a fairly large number of children did. Also when asked, 'Have you ever played any game in which knowledge of direction was essentially required?', a majority of Sanskrit school children answered 'yes', whereas a majority of Hindi school children answered 'no'.

The results of the language elicitation task (route description) presented in the second room (blindfold removed) are presented in Table 3. They are classified into G+ (All or all but one of the segments are described correctly with geocentric language), G- (Geocentric language is used, but incorrectly for more than one segment) and E (Egocentric language). It might be noted that all participants had used G+ language on previous tests, so any change in language reflects the impact of the disorienting procedure.

The findings reveal that all Sanskrit school children continue to use correct geocentric language at the end of the procedure, as well as more than half of the Hindi school children. However, seven of the latter (26%) do get disoriented and hence get the directions of the path

Table 3. Language used on route description by different levels of experts in Sanskrit and Hindi schools

	Level 1 experts	Level 2 experts		Level 3 experts	
Total					
Sanskrit school	G+	2	4	18	24
Hindi school	G+	5	5	6	16
	G–	1	4	2	7
	E	1	1	2	4

G+: Correct geocentric; G-: Incorrect geocentric; E: Egocentric.

segments wrong. This includes two of the level 3 experts, who seemingly had carried directions all the way into the second room; possibly they had just been lucky in guessing the correct directions when still blindfolded. Four of the children (15%) change to egocentric language, which is an easy way out of the conundrum, or, in other words, a smart choice for someone who has both frames of reference at her/his disposal.

Discussion

The findings of the study indicate that almost all children tended to count turns and mentally keep track of directions. They generally did not use external cues other than the sun, and usually agreed that their previous experience with sunrise (i.e. locating East) was helpful in judging directions. On the other hand, the level 3 experts tended to use a kind of active dynamic process to keep directions in mind (reckoning and tracking), while the experts of other levels seemed to rely on a more passive knowledge base. Mothers, fathers and teachers were the major sources of knowledge about directions for almost all of them, showing that this knowledge is actively transmitted in both formal and informal education.

A difference in the transmission of knowledge about directions can be noted between Sanskrit and Hindi school children. In the case of the latter, the emphasis is mainly on the learning of cardinal directions in the school to a level that they may at least be correctly identified by children on the school premises. In this process of teaching-learning, the orientation is mainly geared with reference to the 'rising sun'. All children seem to remember a poem that tells them how to get to other directions from the rising sun. Such a process necessarily entails the computation of other directions based on the knowledge of East. Thus, any error in identifying East, either by chance or with disorientation, is likely to generate error in finding other directions.

In the case of Sanskrit school children, the transmission of knowledge about directions occurs in a more active manner. Children are not only taught about the 10 cardinal directions along with their cultural significance, but they are also required to use them in their day-to-day practice (e.g. in morning and evening prayers) in close supervision by either a teacher or senior peers. Those who make errors in this process get them corrected with some lessons about how to guard against such errors in judgment. For the immediate surrounding they are generally asked to make use of a number of cues available locally (e.g. the main door of the hall, or the main gate of the school, the location of the street, or noises coming from the street, etc.). For unfamiliar locations, they are asked to look at a temple to correctly orient themselves. For example, in a Shiva temple, the statue is oriented to the north, which is also underlined by the presence of another statue of a bull outside the main hall of the temple. Other temples are also characterized by specific spatial orientations not only of their deities, but also of other arrangements within and outside the temple premises. Certain kinds of trees planted around houses also carry highly accurate information about directions. While walking around with their teachers or classmates, Sanskrit school children are taught the value of these environmental features, which they can use anywhere to know directions. Such reference points become a part of their cognitive structure that can differentiate among directions even in situations of limited cue availability.

Evidence for this can be found in many Sanskrit school children who described a process called '*andaaz*' to keep track of directions in the blindfold condition. It is difficult to provide an exact translation of this concept in English. As we have indicated earlier, it refers to a process of making fine and accurate judgments. Although '*andaaz*' develops on the basis of one's habitual experiences of a given situation, in its mature form the process becomes automatic, and is carried on almost unconsciously. In this sense, '*andaaz*' represents a cognitive process, which can be considered as synonymous with 'reckoning'. The children who use '*andaaz*' live with directions, move with them, and can 'just tell' them at any time, without making special efforts. These children also seem to be highly sensitive to salient cues to guard against errors in the judgment of directions. We have noted that some level 3 experts in the Sanskrit-medium school indicated using more varied sources of knowledge about directions than other children. This aspect was also evident in the salience of directions when engaging in other activities (e.g. eating, sleeping and worship). These observations indicate that certain specific experiences and activities such as those observed in Sanskrit school children facilitate the development and deployment of the dead-reckoning process.

In recent years, the notion of 'embodied cognition' has been used in relation to the process of dead reckoning. It involves the idea that cognitive processes develop through real-time, goal-directed interactions between individuals and their environment, that sensory and motor experiences form the basis of cognition, and that mind, body and the world mutually interact and influence one another to promote an organism's adaptive success. Embodied cognition theorists try to link the abstract mental abilities to people's fundamental sensory and motor experiences in the real world. Lakoff and Núñes (2000) indicate that a weak form of 'embodied cognition' would look for a physical neural structure for carrying out cognitive activities, such as '*andaaz*' in our study, whereas in a stronger form, the notion can be used to explain the process at an abstract and unconscious level. In our study we find evidence to suggest that dead reckoning has a basis in the day-to-day experiences of children. While lesser experts may rely on a number of physical external cues (e.g. sun, street noise) to find out directions, the real experts can do it in a more automatic manner even in the absence of apparent physical cues in the situation.

Taken as a whole, the level of children's performance from both categories of schools is quite impressive, since they could solve the blindfold situation clearly in one room, but many could also do it after moving to another room. Given the fact that we had tried our best to eliminate any unexpected cues that might give children clues about directions, the overall performance of Sanskrit- and Hindi-medium school children (82 and 74% correct, respectively) in the blindfold test would allow them to be labelled as 'good dead reckoners'. In our study with children in Geneva (Dasen et al., 2006), not a single egocentric child could tell cardinal directions inside a room, nor even outside.

However, the inability of some children to hold on to directions accurately in the blindfold condition in the other room raises doubt about the strong claim that the use of a geocentric frame of reference is the only factor associated with dead reckoning. The findings indicate that dead reckoning seemingly does not entirely depend on the salience of cardinal directions in the children's day-to-day life. Hence, the findings of the present study do not provide us with very strong evidence for admitting the existence of 'dead reckoning' as a general process available with geocentric language speakers. It is not general in the sense of being an automatic skill of all geocentric frame users. In other words, speaking a geocentric language is a necessary but not a sufficient condition for good dead reckoning, and there are more individual differences than expected from Levinson's (2003) theory.

One difference between the examples mentioned by Levinson and our situation is that Hindi has the particularity of providing all three frames of reference, and even if the geocentric one is favoured through cultural, and particularly religious, norms and practices, the egocentric frame remains there as an option. We are facing a cognitive style in which individuals have all the linguistic and cognitive processes at their disposal, but make some choices according to circumstances. These choices may not always be conscious, and they are heavily influenced by ecological and cultural factors (as other parts of our research demonstrate). The limits of a cognitive style interpretation are reached in the case of European language speakers, since, even though the geocentric option is theoretically available, it is never used for small-scale space.

These findings tend to support Levinson (2003) when he suggests the possibility of strong dead reckoning among absolute language speakers, but also when he hesitates in attributing a direct causal connection between language and dead-reckoning abilities, and in considering this relationship to be universal. It may be noted here that dead reckoning in the normal course includes using all available cues, but possibly with a fine analogical adjustment. In our study we made the process more difficult by cutting out visual and other cues as much as possible, and the subjects also did not really have to navigate through space, but had to keep an orientation system in their heads to locate themselves in relation to cardinal directions.

Given this level of complexity in the situation, how can we explain that the dead-reckoning process was more strongly developed in Sanskrit- than Hindi-medium school children in spite of the fact that both groups were absolute language users? Intensive interviews carried out with some Sanskrit school children (who seemingly carried directions all the time with them) are useful in providing a tentative answer to this question. When asked how they could sense the direction even with blindfolded eyes, the children generally referred to a game that they sometimes played at home. In this game, a child gets blindfolded, his or her hands are filled with sand or dust, and a small stick is placed vertically on it. Then he is carried by another child quite a bit away from the place. The child's journey involves several turns before reaching a point where the sand is poured on the floor and the little stick is hidden in it. Then the child is carried back to the initial place through a new route, again with several turns. On reaching the starting point of the initial journey, the blindfold is removed, and the child is asked to search out the place where the sand and the stick were hidden.

Further probing with Sanskrit school children revealed that as students of the school, they played this game and some others (in which directions had to be located while blindfolded) at school fairly regularly. While many children in the Hindi-medium school were also aware of these games (and some older ones had also actually participated in them as kids), they did not remember having organized or participated in such activities for several years. It appears that certain activities and routines of life encourage the development of the dead-reckoning process. Sanskrit-medium school children's reliance on dead reckoning in judging accurate directions under blindfold conditions of the study might be attributed to the fact that they regularly participate in activities that call upon the use of dead reckoning. Owing to the specific demands of their daily life, they seem to develop cognitive characteristics which are less likely in children (e.g. of the Hindi school) who negotiate life in a slightly different setting, even if both are versed in geocentric language use.

We have indicated earlier that dead reckoning involves keeping track of orientation by integrating information concerning movement without needing a reference to recognized features. Hence, this process is likely to be influenced by 'attention demands' of the situation. It may be noted that relatively automatic skills (e.g. movement in familiar environments) do not demand much attention, whereas skills requiring control and effort (e.g. finding one's way in unfamiliar environments) demand a great deal of attention. Keeping track of direction when blindfolded may partly involve reliance on calibration of body movements, but this strategy is more likely to work in situations when the movements are simple and easy to code in left and right turns. When the movements involve a complex pattern, body-based information does not seem to be adequate for keeping track of directions. Sanskrit school children, who have access to 10 cardinal directions (8 of them with precise angles) are likely to manipulate directions mentally in more efficient ways than those whose spatial knowledge is organized in egocentric terms mainly with reference to left and right.

Concluding Remarks

This study certainly has some limitations, notably linked to quasi-experimental research: that is, working with socio-cultural facts that cannot be produced experimentally. For example, there is a confound between the two types of schools and gender, with boys only in the Sanskrit school and mostly girls in the Hindi-medium school. While this bias also exists in our main study, it is less pronounced, since we do have data from a Sanskrit school for girls. Our analyses indicated that gender is not an important variable in this context, although there are differences in socialization practices that could be relevant, for example the kind of games that are played. Another aspect that was difficult to control was the possibility that additional cues may occasionally have been available; since the study was carried out in schools and not in the laboratory, some noise did occasionally come from neighboring classrooms. Also, keeping track of the position of the experimenters may have helped in updating information about orientation. However we have found that it is those who are already expert in dead reckoning who are able to take these additional cues into account. So we believe that such minor experimental defects do not threaten our conclusion. In (cross-)cultural psychology, there is always a trade-off between control and cultural validity (Mishra & Dasen, 2007).

Our research on the development of the geocentric frame of reference, in this particular study and in our larger project, should contribute to lessen the ethnocentrism of mainstream developmental and cognitive psychology. We are documenting a cognitive process that has received scant attention because it is not familiar to the Western world, where most of the psychological research takes place. But beyond documenting a cultural curiosity, this research allows us to raise some more general theoretical issues. For example, in the old debate about the universality or cultural specificity of cognitive processes, we find that all three spatial frames of reference are generally available, but ecological, cultural and socio-historical conditions determine which is more likely to be used. In other words, there is a cognitive style, with distinct cultural preferences for one style over another, up to the limit where the geocentric frame is virtually unknown to Western children and even adults. There are some indications in Troadec's (2007) research with French children, however, that show that a geocentric frame could be actualized through learning.

Another important theoretical issue is linguistic relativism, which has continued to be in debate almost for the last five decades. The hypothesis has obvious implications for the development of language and cognition (Gentner & Goldin-Meadow, 2003). Among the developmental psychologists, Piaget (1968) recognized the reciprocal nature of language and cognitive development, but did not give much importance to language in cognitive development. In fact, he considered the possibility of language only by the representational capabilities of cognition. On the other hand, Vygotsky (1934/1962) argued for an interactive relationship between language and cognitive development. He acknowledged the independent development of language and cognition in the early years of a child's life, but greatly emphasized the interdependence of language and thought in later years of development by suggesting that 'learning to direct one's own mental processes with the aid of words or signs is an integral part of the process of concept development' (p. 59).

Gumperz and Levinson (1996) have revived the classical Sapir–Whorf hypothesis. In more recent years, Levinson (2003) and his team claimed that language is the sole and only determinant of cognition. Our research studies, however, support only a moderate form of linguistic relativity. They demonstrate that language is itself part of a much wider eco-cultural system, comprising such aspects as cosmologies and belief systems, religion and values, that surround the developmental niche in which knowledge and skills, such as geocentric dead reckoning, are co-constructed (Dasen, 2003; Valsiner, 2000).

Acknowledgements

This research was supported by grant 1113–067178 of the Swiss National Science Foundation. We thank Aparna Vajpayee and Surabhi Prakash for collecting the data. We are also grateful to the Netherlands Institute for Advanced Study (NIAS) for providing Ramesh Mishra with the opportunity, as its Fellow-in-Residence, to complete this paper.

References

Brooks, R.A. (1991) How to build complete creatures rather than isolated cognitive simulators. In K. VanLehn (Ed.), *Architectures for intelligence: The 22nd Carnegie–Mellon symposium on cognition* (pp. 225–239). Hillsdale, NJ: Erlbaum.

Burch, D. (1986). *Emergency navigation.* Camden, ME: International Marine.

Cablitz, G. (2006). *Marquesan—a grammar of space*. Berlin: Walter de Gruyter.

Cornell, E.H., & Heth, D.C. (2004). Memories of travel: Dead reckoning within the cognitive map. In G.A. Allen (Ed.), *Human spatial memory: Remembering where* (pp. 191–215). Mahwah, NJ: Erlbaum.

Cottereau-Reiss, P. (1999). L'espace kanak ou comment ne pas perdre son latin! *Annales de la Fondation Fyssen*, *14*, 34–45.

Dasen, P.R. (2003). Theoretical frameworks in cross-cultural developmental psychology: An attempt at integration. In T.S. Saraswathi (Ed.), *Cross-cultural perspectives in human development* (pp. 128–165). New Delhi/Thousand Oaks, CA: Sage.

Dasen, P.R., Mishra, R.C., Niraula, S., & Wassmann, J. (2006). Développement du langage et de la cognition spatiale géocentrique. *Enfance*, *58*, 146–158.

Gentner, D., & Goldin-Meadow, S. (2003). *Language in mind: Advances in the study of language and thought.* Cambridge, MA: MIT Press.

Gladwin, T. (1970). *East is a Big Bird: Navigation and logic on Puluwat Atoll*. Cambridge, MA: Harvard University Press.

Greidanus, E. (2002). *The representation of dead reckoning during a suburban walk.* Unpublished manuscript, University of Alberta, Edmonton, Alberta, Canada.

Gumperz, J.J., & Levinson, S.C. (1996). *Rethinking linguistic relativity.* Cambridge: Cambridge University Press.

Hegarty, M. (2004). Mechanical reasoning by mental simulation. *Trends in Cognitive Science*, *8*, 280–285.

Hutchins, E. (1983). Understanding Micronesian navigation. In D. Gentner & A. Stevens (Eds.), *Mental models* (pp. 191–225). Hillsdale, NJ: Erlbaum.

Huttenlocher, J. (2005). Mental representation. In J. Rieser, J. Lockman, & C. Nelson (Eds.), *Action as organizer of learning and development* (pp. 221–241). Mahwah, NJ: Erlbaum.

Klatzky, R.L. (1998). Allocentric and egocentric spatial representations. Definitions, distinctions, and interconnections. In C. Freksa, C. Habel, & K.F. Wender (Eds.), *Spatial cognition: An interdisciplinary approach to representation and processing of spatial knowledge* (pp. 1–17). Berlin: Springer-Verlag.

Lakoff, G, & Núñes, R.E. (2000). *Where mathematics comes from: How the embodied mind brings mathematics into being*. New York: Basic Books.

Levinson, S. (2003). *Space in language and cognition*. Cambridge: Cambridge University Press.

Mishra, R.C., & Dasen, P.R. (2005). Spatial language and cognitive development in India: An urban/rural comparison. In W. Friedelmeier, P. Chakkarath, & B. Schwarz (Eds.), *Culture and human development: The importance of cross-cultural research to the social sciences* (pp. 153–179). New York: Psychology Press.

Mishra, R.C., & Dasen, P.R. (2007). The methodological interface of psychology and anthropology. In J. Wassmann & K. Stockhaus (Eds.), *Experiencing new worlds* (pp. 21–35). Oxford: Berghahn.

Mishra, R.C., Dasen, P., & Niraula, S. (2003). Ecology, language and performance on spatial cognitive tasks. *International Journal of Psychology*, *38*, 366–383.

Mishra, R.C., & Vajpayee, A. (2008). Sanskrit schools in India. In P.R. Dasen & A. Akkari (Eds.), *Educational theories and practices from the majority world* (pp. 245–267). New Delhi: Sage.

Mittelstaedt, H., & Mittelstaedt, M.L. (1982). Homing by path integration. In F. Papi & H. Wallraff (Eds.), *Avian navigation* (pp. 290–297). Berlin: Springer.

Newcombe, N.S., & Huttenlocher, J. (2006). Development of spatial cognition. In W. Damon, R.M. Lerner, D. Kuhn, & R.S. Siegler (Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception and language* (pp. 734–776). New York: Wiley.

Niraula, S., Mishra, R.C., & Dasen, P. (2004). Linguistic relativity and spatial concept evelopment in Nepal. *Psychology and Developing Societies*, *17*, 99–124.

Piaget, J. (1986). *Six psychological studies.* New York: Vintage.

Piaget, J., & Inhelder. B. (1967). *The child's conception of space*. New York: Norton. (Original work published 1948.)

Pederson, E. (1993). Geographic and manipulable space in two Tamil linguistic systems. In A.U. Frank & I. Campari (Eds.), *Spatial information theory* (pp. 294–311). Berlin: Springer.

Rieser, J.J. (1999). Dynamic spatial orientation and the coupling of representation and action. In R. Golledge (Ed.), *Wayfinding behavior: Cognitive mapping and other spatial processes* (pp. 168–190). Baltimore, MD: Johns Hopkins University Press.

Simmering, V.R., & Spencer, J.P. (2007). Carving up space at imaginary joints: Can people mentally impose arbitrary spatial category boundaries? *Journal of Experimental Psychology: Human Perception and Performance*, *33*, 871–894.

Spelke, E.S., & Newport, E. (1998). Nativism, empiricism, and the development of knowledge. In W. Damon & R.M. Lerner (Eds.), *Handbook of child psychology: Vol. 1. Theoretical models of human development* (5th ed., pp. 165–179). New York: Wiley.
Taylor, H.A., & Tversky, B. (1996). Perspective in spatial descriptions. *Journal of Memory and Language*, *35*, 371–391.
Thelen, E., & Smith, L.B. (1994). *A dynamic systems approach to the development of cognition and action.* Cambridge, MA: MIT Press.
Troadec, B. (2007). *Psychologie culturelle : Le développement cognitif est-il culturel?* Paris: Belin.
Vajpayee, A., Dasen, P.R., & Mishra, R.C. (2008). Spatial encoding: A comparison of Sanskrit- and Hindi-medium schools. In N. Srinivasan, A.K. Gupta & J. Pandey (Eds.), *Advances in cognitive science* (pp. 255–265). New Delhi: Sage.
Valsiner, J. (2000). *Culture and human development: An introduction*. London: Sage.
Vygotsky, L.S. (1962). *Thought and language*. Cambridge, MA: MIT Press. (Original work published 1934.)
Warren, W.H. (2005). Information, representation and dynamics: A discussion of the chapters by Lee, von Hofsten, and Adolf. In J. Rieser, J. Lockman, & C. Nelson (Eds.), *Action as organizer of learning and development* (pp. 123–36). Mahwah, NJ: Erlbaum.

Biographies

RAMESH MISHRA is Professor of Psychology at Banaras Hindu University, India. He has studied cognitive development of schooled and unschooled children in the widely varying cultural contexts of India by combining methods of observation and experimentation. He is also interested in the study of social and cultural change and its effect on human development. ADDRESS: Ramesh C. Mishra, Department of Psychology, Banaras Hindu University, Varanasi 221 005, India. [email: rcmishra_2000@yahoo.com]

SUNITA SINGH is a doctoral student in the Department of Psychology, Banaras Hindu University, India. She is interested in the study of cognitive development of school-age children in relation to their experiential and cultural background. [email: singhdimple1@yahoomail.com]

PIERRE R. DASEN is Emeritus Professor of Anthropology of Education and Cross-cultural Psychology. His research has been concerned mainly with cognitive development in various cultural contexts. He is interested in combining methods from cultural anthropology and developmental psychology. [email: pierre.dasen@unige.ch]