GEOCENTRIC DEAD RECKONING IN SANSKRIT- AND HINDI-MEDIUM
SCHOOL CHILDREN

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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:

Spatial language and cognition, orientation systems, geocentric dead reckoning, cross-cultural human development, Sanskrit schools, Hindu religious practices
Directed movements in space seem to be essential for 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 to reach desired goals. The kind of information they use, and the manner in which they are able to do so, have been the lively issues of debate 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 increasing spatial competence among them. While Piaget’s theory has been widely used in research on spatial cognitive development with considerable empirical support, some research grounded in strong nativist theory suggests that even infants are equipped with specific knowledge of the spatial world (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 into 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 carry out many mechanical activities in thought (e.g., reasoning about the functions of gears or pulleys). Some researchers (e.g., Brooks, 1991) raise questions about the scientific necessity of using the notion of representations, and others (e.g., Thelen & Smith, 1994, Warren, 2005) advise to do away with them. 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. On the other hand, some researchers (e.g., Huttenlocher, 2005) consider representations essential for explaining behavior of individuals on various cognitive tasks.

Research by Piaget and Inhelder (1948/1967) suggests that spatial knowledge of adults is accurate, metric and well structured, involving a Euclidean system of spatial representation. As a result, they are able to easily
remember and reconstruct spatial lay outs, take perspective of others, perform variety of spatial tasks which appear to be difficult for children, and use spatial representations based on a coordinate system. Although such a characterization of adult spatial thought has been questioned in recent years (see Newcombe & Huttenlocher, 2005), 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, children 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 objects-centred, viewer-centred and environment-centred 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. 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., left, right, front, and back). In an absolute frame, the objects are defined with reference to cardinal directions (e.g., north, south, east and west). 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 the preference is 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 (Pederson, 1993; Levinson, 2003, p. 182). 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, both in language and encoding, an absolute frame with reference to cardinal directions (e.g., North, South, East, West), often supported by some obvious local landmarks known to every one (e.g., temple, road, or pond). In urban settings, where the use of left-right is more functional in terms of negotiation of life through streets and alleys, the egocentric frame of reference (mainly left, right) gradually tends to appear in peoples’ language and, to some extent, in the encoding of spatial arrays.

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 in places like 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 ones’ position in relation to them all the time appears to be relevant to a geocentric frame of orientation. The process through which people constantly update their spatial position in the environment is called “dead reckoning”. This process differs from that of “tracking” in which people constantly seem to engage in some sort of computation while walking in an unfamiliar space. 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 current location. Historical records show that Columbus’ guesses were often way off reality. Very sophisticated 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 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) have provided evidence in support of the first viewpoint. They tested the ability of subjects to remember the location of a ship on a table top, and to estimate its location after a 10-second delay relative to some visible dots (called real island condition) and in the absence of those dots (called imagined virtual island condition). It was found that in the latter condition, the subjects behaved as if the dots had never been there. In an interview, the subjects not only indicated that they were able to impose the dots mentally, but they also generally over-estimated their mental abilities 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 strongly claimed that even people like Micronesian seamen 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 the use of mentally imposed
reference points, nor did it focus on the processes involved in the sea navigation skill that develops over a long period of time in the face of several risks and challenges at the sea.

In contrast to the claim for a physical cue-based navigation process, some research shows that human’s movement on the ground is represented cognitively like a survey of the territory as seen from the 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 location of other objects, or landmarks in the space.

Greidanus (2002) blindfolded university students and led them for walking along a path in an unfamiliar suburban neighborhood. 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 paths. Blindfold 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, sensations of movement need to be monitored for long periods without calibrations against known landmarks. According to Burch (1986) dead reckoning requires that the navigator must not only be able to calculate speed, time, and direction of travel, but also 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 away from the target island, 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” (Newcombe & Huttenlocher, 2006), one gets the impression as if 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, p.9) concludes that “on the whole, the literature is suggestive of a more accurate representation of egocentric parameters than allocentric parameters”, 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 movements are not at all linked to
Many people can carry geocentric references wherever they go, and can relate themselves 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, allowed 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 judgments 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 in all situations were remarkably accurate. 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 “woody”), 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.” At the very least, the needs of the linguistic output system are going to level out the kind of individual differences we are likely to find elsewhere. (Levinson, 2003, 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” (Levinson, 2003, p. 243).
Cottereau-Reiss (1999) also used a blindfold situation for language elicitation with a few children. Children played this game by 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 (Cottereau-Reiss, personal communication) 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, Cabilitz (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 found it difficult to do so when taken to an unfamiliar setting.

The purpose of this study is 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 if 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 (eight with precise angles) instead of 4. The latter is the case in 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 of life is unique in many respects. A precise description of spatial language in Sanskrit literature is found in *Rig Veda*, which is an important and the oldest Hindu religious scripture. The hymns of the *Rig Veda* are composed in the praise of deities like fire, wind, water, sun, moon, etc. 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 rising and setting of the sun give us a measure of time, called day and night, which together constitute a day. The full and new moon give us the dark and bright fortnights, and taken together they form a month. Thus, the Hindu system believes in the existence of 30 days in a month. For almost six months, the sun has its leaning to the South, and for another six months, it has leaning to the North. Thus, a year consists of 12 lunar months, with 30 days to each month, making a total of 360 days. In the *Rig Veda* these are poetically mentioned as “the wheel of the sun with its 360 knobs”.

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 ten segments, each defining a particular direction. These directions are named as *uttar* (North), *dakshin* (South), *purva* (East), *pashchim* (West), *ishan* (NorthEast), *agneya* (SouthEast), *vayavya* (NorthWest), *nairitya* (SouthWest), *urdhava* (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” since the early years of life 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 (in press) 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 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.

In a previous study Vajpayee, Dasen and Mishra (2008) had compared 10-14 year Sanskrit- and Hindi-medium school children with respect to the knowledge of cardinal directions as well as the 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. A comparison of cognitive performance in terms of the R-A gradient (proportion of geocentric responses) indicated a relatively higher Geocentric encoding on all spatial cognitive tasks on the part of Sanskrit 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., Kohs Block Designs Test).

Sample and Design

The study, which is the 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.

Our study with children in these schools (Vajpayee, Dasen, & Mishra, 2007) had found that they were using predominantly a geocentric frame of
reference in performance of spatial tasks. Even though the Hindi-medium school children are also of Hindu faith, Sanskrit-medium education entails both a cosmology and behavioural practices that are relevant for geocentric spatial orientation. The cultural practices and daily-life routines of Sanskrit-medium school children are organized in such a manner that they tend to encourage the use of a geocentric frame of reference in various contexts (e.g., remembering East and West for morning and evening prayers, avoiding South is arrangements for sleeping and eating, etc.) more often than they do in the case of Hindi-medium school children.

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 02 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 if not impossible, because these children would fail systematically our procedure, and were extremely frustrated. Hence the study does not include such a control group.

**Procedure**

Children were taken individually to a room on their school compound, which was unfamiliar to them, and which had no windows. They were asked to indicate the four cardinal directions (i.e., East, West, North and South), first with eyes open, then with eyes blindfold and spun around three and quarter times (so that they did not face the initial direction). The responses were recorded. Then they were helped to walk to another room with blindfold eyes. Movement between the two places required several turns. In the new room, they were again spun around three and 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 an outline, see Mishra & Dasen, 2005). The experimenter moved along the path with blindfold eyes, and the children had to guide her verbally on how to proceed on the path. The directions given by 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. Also, 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 3 Experts” (all directions correct with open-eyes inside a room with no windows, blindfold, and also in the second room), “Level 2 Experts” (all directions correct with open-eyes and blindfold, but not in the second room), and “Level 1 Experts” (all directions correct with open-eyes, but not with blindfold, nor in the second room). The distribution of different levels of experts in the two category of schools is given in Table 1.
Table 1: Distribution of different levels of experts in Sanskrit and Hindi schools

<table>
<thead>
<tr>
<th></th>
<th>Level 3 experts</th>
<th>Level 2 experts</th>
<th>Level 1 experts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanskrit</td>
<td>18</td>
<td>3</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>Hindi</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>13</td>
<td>9</td>
<td>50</td>
</tr>
</tbody>
</table>

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 the groups were mainly geocentric in their language and encoding.

This difference between the two school types provided us with an opportunity to compare Sanskrit- and Hindi-school children in terms of 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.
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.

<table>
<thead>
<tr>
<th>Levels of expertise</th>
<th>Sanskrit school</th>
<th>Hindi school</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 3 (N=18)</td>
<td>Levels 2 + 1 (N=6)</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reckoning</td>
<td>50</td>
<td>67</td>
</tr>
<tr>
<td>Tracking</td>
<td>61</td>
<td>17</td>
</tr>
<tr>
<td>Movement of body</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>Prior knowledge</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td><strong>Awareness</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sun</td>
<td>44</td>
<td>83</td>
</tr>
<tr>
<td>Other</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td><strong>Sources of Knowledge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher</td>
<td>50</td>
<td>83</td>
</tr>
<tr>
<td>Mother</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Father</td>
<td>67</td>
<td>50</td>
</tr>
<tr>
<td>Brother/Sister</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>Books</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>Experiences</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td><strong>Salience of directions in daily life</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Sleeping</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>Worshipping</td>
<td>94</td>
<td>100</td>
</tr>
</tbody>
</table>

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: 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 analyse 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 (for example, 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 socialisation, both in the family and at school. Sanskrit school pupils indicated “teachers” more often than Hindi-school pupils, which is in line with that school’s curriculum. Mother and especially
father are important sources of knowledge, indicating that this socialization occurs but at home and in 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 was somewhat more salient for Sanskrit than Hindi school children for organizing activities like eating and worshipping and sleeping (particularly to avoid facing South). We have already examined the salience 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 it here”, a majority of Hindi school children answered “yes” indicating that they were quite confident of doing so. In the Sanskrit school, on the other hand, 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 even a single child in the Hindi school indicated to be able to do so, whereas in the Sanskrit school, a fairly large number of children indicated to be able to do so. 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, and at the beginning of the procedure. So, any change in language reflects the impact of the disorienting procedure.
Table 3: Language used on route description by different levels of experts in Sanskrit and Hindi schools

<table>
<thead>
<tr>
<th></th>
<th>Level 3 experts</th>
<th>Level 2 experts</th>
<th>Level 1 experts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sanskrit school</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G+</td>
<td>18</td>
<td>3</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>G-</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td><strong>Hindi school</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G+</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>G-</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

G+ Correct geocentric, G- Incorrect geocentric, E Egocentric

The findings reveal that all Sanskrit school children continue to use correct geocentric language at the end of the procedure, and so do more than half of the Hindi-school children. However, 7 of the latter (26%) do get disoriented and hence get the directions of the path segments wrong. This includes two of the level 3 experts, who seemingly had kept 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, we could say, 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 on steps and mentally keep the 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 to almost all of them, showing that this knowledge is actively transmitted in both formal and informal education.

On the other hand, 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 be correctly identified by children at the school premises at least. In this process of teaching-learning, the orientation is mainly geared with reference to the “rising sun”. All children seem to remember a poem in the school that tells them how to get to other directions from the main direction of sun. Such a process necessarily entails the computation of other directions based on the knowledge of East (sun rise). Thus, any error in identifying East, either by chance or with disorientation, is likely to generate error in getting to 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 ten cardinal directions in the school along with their cultural significance, but are also required to use them in their day-to-day practice (e.g., in morning and evening prayers) in close supervision of either a teacher or the senior inmates of the school. 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 street, or noises coming from the street side, and so on. For unfamiliar locations, they are asked to look at a temple to correctly orient them. For example, in a Shiva temple, the statue in principle is oriented to north, which is also signified 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 its 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 senior inmates, Sanskrit school children are taught the value of these environmental features, which they can use anywhere for knowing 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 language. 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 in an unconscious
manner. 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 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 (e.g., books,
learning experiences) than other children. This aspect was also evident in the
salience of directions in terms of engaging in other activities (e.g., eating,
sleeping and worship) that showed considerable variation across the groups.
These observations indicate that certain specific experiences and activities
such as those observed in the case of Sanskrit school children facilitate the
development and deployment of dead reckoning process.

In recent years the notion of “embodied cognition” has been used in
interpreting 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 world mutually interact and
influence one another to promote an organism’s adaptive success. The
embodied cognition theorists try to link the abstract mental abilities to peoples’
fundamental sensory and motor experiences in the real world. Lakoff and
Nunez (2000) indicate that a weak form of “embodied cognition” would look
for a physical neural structure for carrying out cognitive activities, such as
“anddaz” 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 day-to-day experiences of children. While less 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 per cent 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 even tell cardinal directions inside a room, and not 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 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 that cardinal directions occupy in 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 necessary but not a sufficient condition for good dead reckoning, and there are more individual differences than Levinson’s (2003) theory would make us expect.

One difference between the examples mentioned by Levinson and our situation is that Hindi language 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 of the study tend to support Levinson (2003) to the extent he suggests the possibility of strong dead reckoning among absolute language speakers, but hesitates in specifying a direct causal connection between language and dead reckoning abilities, and in considering this relationship as 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 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 could 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 blindfold eyes, the children generally referred to a play in which they got engaged as kids in a similar kind of activity at home. In this play, a child gets blindfolded, his hands are filled with dry sand or mud powder, and a small stick is installed on it in a vertical position. 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, and 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 inmates of the school, they were organizing this play and some others (in which directions had to be located while blindfold) in the school premises almost on a regular basis. While many children in the Hindi-medium school were also aware of these play activities (and some old ones had also actually participated in them as kids), they did not remember organizing or participating in such activities during the last several years. It appears that certain activities and routines of life encourage the development of 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 their habitual engagement in activities that call upon the use of dead reckoning on a regular basis. Due to the specific demands of their daily life, they seem to develop cognitive characteristics, which are less likely with children (e.g., of the Hindi school) who negotiate life in a slightly different context, although both still are versed in geocentric language use.

We have indicated earlier that dead reckoning, involves orientation relative to a start location by integrating all information concerning movement without 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 controlled or effortful skills (e.g., way-finding in unfamiliar environments) demand a great deal of attention. Keeping track of direction in a blindfold condition of walk 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 couple of left and right turns. When the movements involve a complex pattern (such as in a blindfold condition), body-based information do not seem to be adequate for keeping track of directions. Sanskrit school children, who have access to ten cardinal directions (eight 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.
References


