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Spatial thought, social thought

Barbara Tversky[1]

Abstract

Spatial thought is not an internalized video of experience but rather a construction carved out of experience. Objects, categories, orderings: These constructive processes sharpen, level, add, subtract, simplify, complicate, and distort, not randomly, but in ways that contribute to sense-making. Parallel phenomena appear in social thought. For example, individuals are grouped into categories, and within-category differences are perceived as smaller than between-category differences. Categories are ordered into dimensions that are spatially arrayed from down to up and from left to right in western languages. These correspondences seem to arise from perception-action couplings, and suggest that spatial cognition can serve as a basis for social thought.

1. Basic facts

We can't escape space. Our bodies take up space, perceive in space, and act in space. Our perceptions and our actions are constrained by space, the things in it, the forces acting in it, the changes in it. We begin to act in space and learn about space even before birth. All our senses participate in that learning, contributing to spatial knowledge. Spatial knowledge is supramodal, informed by vision, hearing, touch, kinesthesis, and more. It is essential to survival. If we didn't know how to get food into our mouths and find our way home, survival would be difficult. This does not mean that our spatial knowledge is perfect. On the contrary. Our spatial knowledge is constructed from ele-

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ments, reference frames, and perspectives. It must reconcile information from different occasions, elements, reference frames, perspectives, and modalities. Reconciling different sources and different information relies on finding common elements and transforming reference frames and perspectives. The reconciliation is approximate, by no means Euclidean, so that it yields systematic biases and errors (e.g., Tversky, 1981, 2005a, 2005b). Despite the fact that knowledge of space is distorted and biased, it serves us well. This is in part because we often only need approximate information, in part because the different biases are independent and can cancel each other, and in part because spatial knowledge is situated, that is, it is used or invoked in environments that provide constraints and information that can serve as correctives.

Spatial knowledge is so fundamental and useful that it serves as a basis for other knowledge, concrete and abstract (e.g., papers in Gattis, 2001). One reminder of the ubiquity of spatial thinking is the ubiquity of spatial metaphors in language. Just as we can't escape space in perception and action, we can't escape space in communication. Spatial metaphors are evident in the ways we talk (and not just in English). We *grow close* to people or *far apart*; one friend is *at the top* of the class and another *descends* into depression; new research *fields open*, other *areas recede* (e.g., Lakoff & Johnson, 1980). Spatial metaphors are evident in the way we visualize abstract concepts on paper; greater weight, pitch, strength, and rating are graphed higher; connections among concepts in networks are drawn as lines, like paths; cyclical processes are represented as circles, paths that start and end at the same place (e.g., Tversky, 2001; Kessell & Tversky, 2005; Tversky, Kugelmass, & Winter, 1991). Spatial metaphors are evident in gesture, where, as in speech and sketch, things that are good or strong or more numerous are gestured upwards, ideas that are more related are gestured as closer; ideas that are ordered conceptually are ordered in space (e.g., Casasanto, 2009; Goldin-Meadow, 2003; Tversky, Heiser, Lee, & Daniel, 2009). These mappings onto space reveal the nature of thought, concrete and abstract. These mappings, especially to an external space that can be viewed and reviewed, also allow and encourage inference, reasoning, and insight, especially through diagrams and gestures, by applying the impressive, highly-practiced spatial reasoning skills of people to reasoning about abstractions, making the effortful intuitive.

How is spatial knowledge organized? The key is objects and the spatial relations among them. Sounds simple, but determining and characterizing the objects and the spatial relations is subtle, relative, and variable. The clues to how spatial knowledge is organized are as multi-modal as the knowledge itself, from the ways that people act, draw, gesture, and talk. Linguistic analyses have been especially insightful (notably, Clark, 1973; Lakoff & Johnson, 1980; Miller & Johnson-Laird, 1976; Talmy, 1983, 2000). Language can be counted on to capture the essential objects, features, concepts, actions, states, and the like that are important for human communication. As others have observed, the perceptual processes and representations that serve human action are coopted in the service of conceptual processes and representations (e.g., Clark, 1973; Lakoff & Johnson, 1980; Shepard & Podgorny, 1978). The facts that abstract ideas from a multitude of domains are conveyed by spatial language, that abstract ideas are mapped to the space of the page, that abstract ideas are expressed by spatial gestures imply that it is spatial thinking that is basic, and that abstract thought is built on spatial thought.

Social cognition is no different. Many intriguing phenomena in social cognition have parallels in spatial cognition. What follows is an analysis of some of what is known about human spatial cognition. Paired with that are allusions to analogous effects in social cognition, some demonstrated, some, to this author's limited knowledge, still to be demonstrated. After that are some speculations about how the transfer from spatial to abstract might happen.

As we begin, a few words on some facts of life, as these inexorable facts about humans and the world constrain perception of and action in space, and, therefore, conceptions of space. First *us*. Humans are for the most part upright, with three axes, an elongated asymmetric vertical axis of head and feet and two orthogonal horizontal axes, the asymmetric front-back axis and the nearly symmetric left-right axis. Our perceptual apparatus is oriented forwards, as is our motor apparatus, conferring a strong asymmetry to the body as well as a privileged direction, forwards. We develop and act in a world that has one powerful asymmetric axis, that of gravity. Gravity has profound effects on the way we develop and act as well as on the world we act in (e.g., Clark, 1973; Cooper & Ross, 1975; Franklin & Tversky, 1990). Going against gravity takes time, force, strength, energy, even money. Children get bigger and stronger and more powerful as they mature, and stronger people are on the whole larger, underlying an association of size with power (Schubert, Waldzus, & Giessner, 2009). These correspondences confer a strong asymmetry on the vertical dimension, as well as a privileged direction, upwards. But there is more in the world besides ourselves.

2. Objects: Groups and categories

The world has an overwhelming amount of stuff, and, what's more, that stuff keeps changing, roads, buildings, bridges, trees, fields, mountains, rivers, lakes, people, clouds, seeds, pebbles, grains of sand, How to keep track of all the stuff, how to remember it, how to predict it, how to act toward it, how to make sense of it all require, at a minimum, the same solution: grouping similar things together (e.g., Rosch, 1978). Otherwise there is an unending number of things and no basis for regularities. Even those things mentioned are already grouped and categorized, and named. But how should things be grouped? By similarity, of course, but things are similar and dissimilar in so many different ways. The best categories contain things that not only look alike but also behave alike, or induce similar behaviors from us. Similarity of features helps identification and similarity of behavior helps inference, prediction, and action.

Good categories, then, share many features, and in particular, share the kinds of features that are likely to be important to human life. Knowing that something is a fruit or an animal or mineral allows a range of important inferences about that thing. Common perceptual features, especially shape, which is especially characteristic of objects, allow rapid identification of objects and common functions or behavior allow knowing what the object might do to us or for us (Tversky & Hemenway, 1983, 1984). For these reasons, red things don't make a good category, even if color is salient so that pre-schoolers often prefer to group things by color than by taxonomic category. Little follows from being *red* or *soft* or *elegant*, that is, color does not support many inferences. These "categories" are usually referred to by an adjective added to *thing*. In contrast, good categories, the ones from which many inferences can be made, are typically referred to by nouns. A noun, then, is likely to refer to a category of things that share many features and from which many inferences can consequently be drawn. Using a noun rather than an adjective to describe something indicates that the thing is likely to share many properties with like things. Indeed, nouns induce stronger inferences (a democrat) than adjectives (democratic) in social descriptions (Carnaghi, Maass, Gresta, Bianchi, Cadinu, & Arcuri, 2008).

As noted, good categories of objects share perceptual features that serve human recognition and share behavioral or functional features that serve human action. What about social categories? The important social categories are people, and many categories of people have characteristic perceptual features that are associated with behavior. Age, gender, and the like have salient perceptual features that cue a wide range of behaviors. Dress, too, provides excellent perceptual cues; it is commonly observed that costume and daily attire, not just physicians' white coats or police uniforms, but the even the kinds of t-shirts and shoes and pants worn by people, are a kind of uniform and can be reasonably reliable cues to age, gender, income, profession, politics, and more.

2.1. Bodies

Undoubtedly the most salient and important object in space is the human body, our own and those of others. Bodies and body parts are famously the source of spatial metaphors, social and other: *heads* of committees, someone's *right hand*, the *foot* of a mountain, the *heart* of the matter, the *arms* and *legs* of chairs and institutions. These metaphoric extensions of the names of parts of the body are based as much in function as in appearance.

Grouping into categories, then, has enormous advantages. But there are rarely advantages without disadvantages; category members can vary widely, they are never identical, but categorizing them means treating all instances equally, as if they were the same. This results in overweighting within-category similarity and between-category differences, a process that leads to biases in judgments of distance of things with actual distances in the world. Thus, students in Ann Arbor thought that university buildings were physically closer to each other than they actually were, and physically farther from town buildings than they actually were (Hirtle & Jonides, 1985). Similarly, Israelis estimate the distances between Israeli settlements or between Arab villages to be relatively smaller than the distances between Israeli settlements and Arab villages (Portugali, 1993). Similarly, distances between members within social groups are estimated to be relatively smaller than comparable distances between members of different social groups. Substituting similarity for distance yields parallel distortions in judgments for social categories. That is, members of the same social groups are perceived to be more similar to each other on irrelevant dimensions and more different from members of other social groups (e.g., Quattrone, 1986).

Reducing the vast quantities of information in the world by categorizing is only a first step. A related second step is to recognize similarities and differences in the categories, and thereby to group categories into larger ones as well as subdivide large ones into smaller ones. Categories can be formed at many levels. Hierarchical grouping has similar effects on inferences as grouping. Students in San Diego incorrectly report that San Diego is west of Reno (Stevens & Coupe, 1978). Presumably this is because people cannot remember all the directions among all pairs of cities. Instead they remember the approximate directions among states, and use the larger groups, the states, to infer the directions of the smaller groups, the cities. Since California is for the most part west of Nevada and San Diego is in California and Reno in Nevada, then San Diego must be west of Reno. Wrong. Social inferences are likely to follow the same paths.

3. Perspectives on objects: Zero, one, and more dimensions

Useful categories not only include and exclude, they also contrast with other categories. A basic distinction for mathematics derives from dimensionality, zero, one, two (three, many). For the mind, by contrast, dimensionality depends not on absolute properties of entities but rather on the perspective taken on them (Talmy, 1983). On a map, Paris can be represented as a point, the route from Paris to Nice as a line, and the entire city of Paris can be represented as an area; just as on a map, also in the mind. Paris can also be thought of as a three-dimensional environment in which people live and work, or, adding time, as a four-dimensional space. The perspectives evident in maps and in conceptions are also evident in language, and are evident in abstract thought. The English prepositions *at, on, in* are clues to zero, one, and two-dimensional thinking respectively. For time this gives us: the train arrived promptly *at* 2; he was *on* hold for an hour; she was *in* the meeting until dinner. And now more abstractly: he was *at* rest, *on* drugs, *in* a quandary. What are the more general implications of conceiving of entities, objects, states as dot-like, line-like, or region-like? Does the implied dimensionality in the language that describes these different emotional states indicate or promote different understandings of the emotional states? Persistent states (note the polysemy) metaphorically or literally enclose people, and constrain their perception and action. As has been seen, persistent states nouns induce stronger inferences (a democrat) than attribute-like adjectives (democratic) suggesting that the dimensional perspective may also affect understanding of social situations (Carnaghi et al., 2008).

4. Locating objects

Once objects in space have been identified and conceptualized, they are located. The mind typically locates objects relatively, not absolutely, one object relative to another object or relative to a frame of reference. Both these processes yield systematic distortions (e.g., Tversky, 1981). The reference object or reference frame can distort judgments. For example, distance estimates from ordinary buildings to landmarks are judged smaller than distance estimates from a landmark to an ordinary building, a reliable error that violates any Euclidean model (Sadalla & Staplin, 1980).

There are several explanations for this reliable phenomenon. One is that a landmark comes to represent not only itself, but an entire region, a category if you will. Indeed, the name of the landmark often names the region; in Manhattan, Times Square, in Washington, DC, DuPont Circle. Similarly,

when asked where they live, people often give the closest landmark. In more abstract domains, landmark categories are essentially prototypes. Prototypical categories induce a similar bias for perceptual stimuli. For example, people judge that a magenta color patch is closer to a red color patch than vice versa. As for landmarks, prototypes like *red* define a broad category that can include a broad range of instances, in this case, shades of red, like magenta, but not vice versa (Rosch, 1978). The power of prototypes or landmark categories extends further to abstract domains: a son is judged to be more similar to his father than the father to his son, and in the Cold War, North Korea was judged more similar to the People's Republic of China than vice versa (Tversky & Gati, 1978). Prototypical social categories are widespread. There are those represented in languages all over the world: mothers, fathers, leaders, and there are those represented by individuals embodying the defining features. We call others the Einsteins or Stalins of the world, though many prominent social categories enjoy only their Warhol fleeting 15 minutes, the latest rock stars or movie actors. From history to hype, less known scientists, tyrants, rock stars, and movie actors are compared to one or more of the prototypes, a short-hand way to confer the attributes of the prototype to the less known person. Prominent landmarks and prominent people in addition to being unique individuals, become categories whose members are similar in location or in distinguishing characteristics.

4.1. Lines and orders

As we have seen, putting things into groups imposes structure on the world by abstracting and selecting similarities and differences and by reducing the number of different things in the world. A deceptively simple process with far-ranging consequences. Organizing the categories into subcategories, hierarchies of kinds or parts, further simplifies and structures the world. Locating objects with respect to other objects and a frame of reference imposes still more structure. Nevertheless, even more structure is needed. Another seemingly simple way to impose structure on the things in the world is to line them up, much as objects can be naturally lined up on the surface of the world, constructing an ordinal scale. Lining things up imposes an order, putting one thing next to another, raising the issue: how to order, in what direction? Putting things on a line opens the further possibility of putting some pairs of things closer, other pairs of things farther, so that not only the order of objects, but also the distances between them are meaningful, thereby constructing an ordinal scale. Finally, when order and distance are meaningful, this raises the possibility of a natural beginning, a natural zero point, such as the ground, from which height is measured upwards and depth downwards. Zero points may be established ad hoc as well, as when distance to many cities is calculated from a particular one.

Just as humans, even tiny ones, naturally form categories and subcategories, they also naturally form orderings (e.g., Gelman & Gallistel, 1976), and can express those orderings using space. One large project investigated how children and adults group and order related things, concrete and abstract, on the space of a page (Tversky et al., 1991). Children and adults, from preschool to college, from three language cultures, English, Hebrew, and Arabic, were asked to put stickers on paper to indicate spatial, temporal, quantitative, and preference relations. For space, the experimenter placed three small dolls in a row, separated by more than the height of the dolls, and asked the child to put stickers on a page showing the locations of the dolls. The adults put X's. Using the space of the page to show spatial relations was easy for the children. Children at all ages put the stickers in a row, spaced apart. Mapping the more abstract concepts to the page, time, quantity, and preference was more challenging. For time, the experimenter placed a sticker in the middle of the page for lunch, and asked the child to place stickers for breakfast and dinner. For quantity, a handful of candy, a bagful of candy, a shelf full of candy. A few children put the stickers on top of each other, or scattered them all over the page, indicating that they conceived of the entities categorically, for example, all meals or separate meals. They did not represent the underlying temporal dimension that connected the meals or the underlying quantity that connected the amounts. Even so, most children, even at four years, put the stickers on a line, indicating that they conceived of the elements, breakfast, lunch, and dinner or disliked food, OK food, and liked food as lying on a dimension, temporal or preference. Furthermore, the more abstract concepts were mapped to a line at a later age than the more concrete concepts, first space, then time, then quantity, then preference.

4.2. Interval: Mapping distance

Ordering categories on dimensions imposes more structure on the world. However, the human mind also discerns relative distances along dimensions. Paris is closer to Amsterdam than Amsterdam to Stockholm. The height of an ant is closer to that of a spider than the height of a spider to the height of a giraffe. A subsequent study asked children to map interval relations, first spatial relations, and then more abstract relations. Mapping spatial, relations that were interval was easy for children. Even the younger children placed stickers farther apart for dolls placed farther apart. However only older children succeeded in mapping distance for abstract concepts, that is, preserving interval relations, to the space of a page. For time for example, children were asked to place stickers to indicate breakfast, morning snack, and dinner. Mapping relative distance or interval for abstract concepts, time, quantity, and preference, was reliable only for children 11 years or more, and, as for ordinal mapping, in the order of abstractness (Tversky et al., 1991). Thus, even children readily order spatial things and abstract things and can express that ordering using real space. Older children can also express distances between things on abstract dimensions, using real space.

4.3. Perspective: Near to far

For judgments of distance in space, the point of view, the anchor or reference point, biases judgments. In one experiment, students in Ann Arbor were asked to imagine themselves either in San Francisco or in New York City (Holyoak & Mah, 1982). They were then asked to make distance judgments from their viewpoint to a set of cities more or less equidistant along an east-west axis between San Francisco and New York City: Pittsburgh, Indianapolis, Kansas City, Denver, and Salt Lake City. Students exaggerated the distances close to their imagined viewpoint relative to the distances far from their viewpoints. Thus, students imagining themselves in New York judged the distance between New York City and Pittsburgh as greater than students whose imagined viewpoint was San Francisco; conversely, students imagining themselves in San Francisco judged the distance from San Francisco to Salt Lake City as greater than those whose viewpoint was New York City. This error is analogous to a phenomenon in viewing a remote vista: the near distances seem greater than the far ones for several reasons: closer objects occlude farther ones, closer ones subtend larger visual angles, and closer ones are sharper than farther ones. When viewing a landscape, near objects are sharp and clear and distant ones blurry.

Events in time form a landscape, too, that invites perspective, with analogous errors and biases. Events in time bear many analogies to objects or landmarks in space (e.g., Casati & Varzi, 1996; Zacks & Tversky, 2001; Tversky, Zacks, & Hard, 2008). Just as concepts of space are organized around the things in it rather than objective measurable Euclidean coordinates, so concepts of time are organized around the events in it. Just as spatial objects can be viewed as zero, one, two or more dimensions, so temporal events can be viewed as zero, one, two or more dimensions. The temporal landscape gets telescoped from our own perspective; near times are rich and detailed and far times are dim and crowded together (Loftus &

Marberger, 1983; Bradburn, Rips, & Shevell, 1987; Brown, Rips, & Shevell, 1985). The temporal landscape, too, has landmarks, and they draw ordinary events closer to them. Just as landmarks in space draw ordinary buildings to them, temporal landmarks draw events in time towards them. For example, the beginnings and ends of semesters are temporal landmarks. Students judge that the events of a semester happened closer to semester beginnings and ends than they actually did. Ordinary events in time do not have this effect (e.g., Huttenlocher, Hedges, & Prohashka, 1988).

There are parallel effects in social judgments to these effects of spatial perspective. People differentiate those "near" us far more than those "distant" from us, so that the people we know are judged to be highly different from one another whereas those we know less well or not at all are judged more similar to one another (Quattrone, 1986).

4.4. Perspectives: Frames of reference

The mind is remarkably agile, and one of its' tricks is imagining other perspectives, sometimes termed *allocentric* perspectives in contrast to current, *egocentric* perspectives. In fact, people can take a variety of different perspectives on experience, real or imagined (e.g., Levinson, 1996; Tipper & Behrman, 1996; Tversky, 1996).

People imagine unseen perspectives when they provide route directions to others to guide them to a destination. People imagine perspectives that conflict with their own when they tell a person facing them which wine glass is theirs (e.g., Mainwaring, Tversky, Ohgishi, & Schiano, 2003; Schober, 1993). Both these perspectives are embedded in an environment, imagining a point of view within it. Even more remarkably, people can take imaginary perspectives above an environment, an overview or survey perspective, and switch rapidly between overview and embedded perspectives (e.g., Lee & Tversky, 2005; Taylor & Tversky, 1992, 1996). Like a map, an overview perspective captures a large environment and provides the links and spatial relations among its parts, the landmarks within it. It eliminates much detail, notably many features on the terrain. For that reason, a survey perspective is useful for getting an overview of the interrelationships among many different places, landmarks, paths. A survey perspective can also be useful planning, for example, a route that joins two specific places, from here to there. By contrast, an embedded perspective provides detail of the environment within view at a level that allows navigation; as navigation proceeds, the view changes and the perspective is updated. Thus, an embedded perspective is useful for the step-by-step details, the set of procedures for getting from one place to another, after a route has been planned.

A route map or route directions represent both space and time, as it takes time to execute each of the steps. Exact distance and exact time are not typically explicit in route maps or route directions, but good approximations to each can be inferred from experience.

These spatial perspectives, survey and route, have analogues to perspectives on time, to construals of time (e.g., Liberman, Trope, & Stephan, 2007; Trope & Liberman, 2003). A survey or broad overview, a calendar for time like a map for space, provides the interrelations among many different entities, temporal or spatial, events or landmarks. A route provides the step-by-step actions needed to get from one place to another. Since events are rooted in places and actions take time, a route is inherently both spatial and temporal. Route plans don't typically provide exact distances or exact times but good approximations to both can often be inferred (Pazzaglia, Meneghetti, & Tversky, unpublished). Liberman, Trope, and their collaborators have shown broad effects of temporal perspective or as they term it, construals of time, on planning and inference. To transform just one of their many examples to the present analysis, thinking about a meeting (or a paper due) in the far future would be done by a survey perspective, looking at the larger temporal landscape that goes from now until after then. However, when the date approaches (or when we approach the date, depending on the temporal metaphor, moving ego or moving time, adopted), a route perspective would be used to plan the steps taken to arrive at the meeting. In a survey perspective, the each event, like the meeting, would be thought of as a point, along with the other temporal landmarks, whereas in a route perspective, the meeting would be thought of as a duration, one dimension encompassing the day to get there, the days of the meeting, the day to return. Thinking about points in surveys and thinking about regions in routes are quite different; points have far less associated detail.

4.5. Symbolic distance

Putting things into categories allows judgments of belonging or not as well as inferences about properties. Breakfast entails a time of day and a kind of cuisine. Ordering things on a line allows a richer set of judgments and comparisons. The speed of making some judgments and inferences depends on the ordinal distance between entities. For example, when asked which of two animals is more intelligent or more pleasant, people respond faster when the animals are far from each other on the dimension of judgment than when they are close to each other, a phenomenon known as the *symbolic distance effect* (e.g., Moyer & Bayer, 1973; Banks & Flora, 1977; Holyoak & Mah, 1981; Paivio, 1978). The foundations for this effect are again spatial. If things were actually lined up in the world, discerning distance between far objects would be easier than discerning distance between near objects. The effect holds for spatial and abstract comparisons, including, naturally, social comparisons.

4.6. Orientation

Orderings in the mind do not necessarily need an orientation, though they may very well have one. One can know that airplanes are more expensive than cars and cars more expensive than airplanes without orienting that ordering in space. Lines on paper representing orders, however, do need an orientation. Here again spatial cognition provides the foundation for orientation, horizontal and vertical. Aspects of the world and the body favor horizontal and vertical. In the world, the horizon is, of course, horizontal, and gravity forms a vertical dimension that maximally contrasts with the horizontal. As for the body, it is typically upright, that is, vertical (or horizontal, in sleep) and navigates the horizontal world. Moreover, visual acuity is greatest for horizontal and vertical lines. Space, whether on paper or in gesture favors horizontal or vertical orientations for ordering. Written language, accounting, calendars, graphs, and more are typically aligned with horizontal and/or vertical.

4.7. Direction

Orderings need a start point and direction as well as a line. For the vertical axis, there are strong asymmetric embodied and situated forces: the vertical human body, which grows upwards from childhood to adulthood, and gravity, which means that going upwards takes more resources than going downwards. The horizontal axis has no strong asymmetric situated forces. However, there are body and cultural asymmetries that appear to affect horizontal orderings, handedness and reading order.

Previews of associations of the axes and their orderings to meaning appeared in the large international study of mappings by children and adults of spatial, temporal, qualitative, quantitative, and preference relations (Tversky et al., 1991). Time, a relatively neutral concept, was primarily mapped horizontally, and the preferred direction for increases corresponded to writing order, left to right for English and right to left for Arabic. For other dimensions, both vertical and horizontal axes were used. Directionality did not depend on reading order. The only bias was to avoid increases from top to bottom.

4.8. Horizontal biases

Most people in the world are right-handed, a fact that is reflected in language; for example, in English, *sinister* derives from the Latin word for *left* and *dexterity* from the Latin word for *right*. Despite these cultural associations, enduring characteristics of the body affect assignment of meaning to space. Left-handers tend to place the things they like on the left, and right-handers tend to place the things they like on the right (Casasanto, 2009). More surprisingly, temporary characteristics of the body also affect meanings. When sitting on a chair tilting left, people are more likely to endorse left political views (Oppenheimer & Trail, 2010).

Another cultural factor, the order of reading and writing, appears to have even stronger effects on assignment of meaning. Reading order is evident in perception and in action: direction of apparent motion corresponds to reading order (Morikawa & McBeath, 1992) as do directions of perceptual exploration and of drawing (e.g., Chokron & De Agostini, 2002; Nachson, 1985; Vaid, this volume; Vaid, Singh, Sakhuja, & Gupta 2002). It is evident in gesture, notably in relating temporal events (Roman, Casasanto, & Santiago, unpublished). It is also evident in mental representations of number, where, for writers of left-to-right languages, smaller numbers are associated with the left side of space and larger numbers with the right side, called the SNARC effect, for Spatial Numeric Association of Response Code (e.g., Dehaene, 1992). This effect reverses for writers of right to left languages and bias is absent in illiterates (Zebian, 2005). Reading/writing order bias is evident in aesthetic judgments (e.g., Chokron & De Agostini, 2000; Nachson, Argaman, & Luria, 1999) and in emotional judgments (Sakhuja, Gupta, Singh, & Vaid, 1996). For R-L languages, power corresponds to reading order, as evident in a bias to graph data for men prior to, that is, to the right of, data for women (Hegarty, Lemieux, & McQueen, in press).

As readers of this volume know, the reading order bias is evident in diverse and surprising ways for social stimuli. Although surveys of (western) fine art in museums show that faces in portraits typically face left, this effect is stronger for female faces than male (Chatterjee, 2001; McManus & Humphrey, 1973). This has been attributed to a bias, present in readers of languages that proceed from left to right, to put agents of actions on the left and patients of action on the right (Chatterjee, 2001, 2002; Maass & Russo, 2003). This *agency hypothesis* is rooted in syntactic properties of language in that most languages follow subject-verb-object or subject-object-verb. To come full circle, it appears that the favored word order is rooted in action, and in particular, in the temporal order of actions evident in the agent-patient-action order of spontaneous gestural explanations favored across many languages (e.g., Goldin-Meadow, So, Ozyurek, & Mylander, 2008) order. The implication for portraits is that men are more likely to be thought of as agents and women as patients, a trend that seems to be weakening as social norms change (Suitner & Maass, 2007). For readers of left-right languages, left-right motion is perceived as stronger than right-left motion, a trend that reverses for readers of left-right languages (Maass, Pagani, & Berta, 2007). Thus, this seemingly arbitrary, probably accidental, convention of writing from the left or from the right has broad consequences for perception, cognition, emotion, and social expectations.

The right-left (or left-right) axis has a weak asymmetry, consonant with the weak left-right asymmetry of the body and the weaker horizontal asymmetries in the world. The fact that languages are written in both directions is further support for the weakness of the asymmetry. The relative weakness of horizontal asymmetries is also supported by the fact that a cultural artifact, the direction of writing, appears to impose asymmetries of thought. Not so for the vertical, aligned with that powerful asymmetric force, gravity, and in fact, it is probably safe to say that all written languages begin at the top.

4.9. Orientation: Vertical biases

The vertical axis of the world, in stark contrast to the horizontal axis of the world, confers a ubiquitous asymmetry on the world. Living things and many of the artifacts designed for them have a vertical axis of symmetry. It is harder to go up than down, it takes more effort, more strength, more power, more resources. In contrast to time and number, quantity and preference were mapped both horizontally and vertically. In the large study investigating mappings of abstract dimensions to the paper of space, increases in quantity and preference were equally likely to be mapped from left to right and from right to left on the horizontal axis, independent of writing order culture, so the direction of the horizontal did not seem to matter. For the vertical, increases were mapped from down to up, but mapping increases from up to down was avoided, undoubtedly due to the strong correspondences between up and more (Tversky et al., 1991).

The strong vertical bias in spatial mapping is well-known in language and in gesture (e.g. Clark, 1973; Cooper & Ross, 1975; Lakoff & Johnson, 1980; Talmy, 2000). *Up* is associated with good, more, powerful, just about every positive attribute, concrete or abstract, social or not. The origins of the association are again spatial: people grow taller and stronger as they grow older, higher piles of money means more money. Defying gravity takes strength. Happy people stand tall and depressed people slump; correspondingly, people may feel "up" or "down." Good performances are given a thumbs-up. Diagrams follow that bias, those produced by novices and those produced by professionals. For example, almost all the evolutionary charts found in biology textbooks in a large university library put man at the top of the evolutionary tree and the present time at the top of charts of geological eras (Tversky, 2001).

5. Spatial schemas

Spatial thinking is deep and complex. Its structure includes objects, and objects located in space with respect to other objects or reference frames; groups of objects, and groups of groups; orderings of objects or groups, and orderings on orderings; intervals between objects and groups, directions, changes, actions; it includes reference objects, background objects, reference frames, perspectives. This is only the surface, only the beginning, but even that is enough to serve as a foundation for the nuances, richness, and creativity of abstract thought. In addition, we have only considered unsituated, disembodied, cerebral judgments of remembered environments, not judgments in the field that include direct perception of the surrounding environment and direct sensations from the body. Effects of the field have been known for years; for example, when people are asked to adjust the orientation of a stick (rod) to upright in the world, their adjustments are affected by the angle of a frame that encloses the stick (e.g., Witkin, Dyk, Faterson, Goodenough, & Karp, 1962). In the field, for example, people overestimate the slopes of hills, especially when they are carrying heavy backpacks (Proffitt, Stefanucci, Banton, & Epstein, 2003). Nor have we considered the effects of social stimuli and spatial ones, and there are intriguing effects. When people are waiting with friends who will climb with them, they reduce their estimates of the slope of the hill (e.g., Schnall, Harber, Stefanucci, & Proffitt, 2008). Fortunately, this is discussed in this volume (Schnall, this volume).

5.1. Spatial schemas: Abstractions

Direct perception of space does not in itself provide groupings, orderings, dimensions, directions, or distances, nor does it provide the variety of perspectives people are able to take, even perspectives that conflict with the physical point of view of the eyes or the body. Indeed, perspectives other than one's own current physical perspective are often preferred to one's own perspective even when the implicit recipient of the message shares the same perspective (Tversky & Hard, 2009). Spatial reasoning is itself an abstraction from information given in perception. It is the abstractions of space, the cognition of space, not the perception of space that is transferred to abstract concepts. As a start, the objects, foreground and background, relations, frames of reference, perspectives, and more on which reasoning is done are not fixed, but rather selected. Imagine being in a busy city scene. Someone stops you to ask for instructions to a restaurant in view. To give instructions, you select the relevant landmarks from the large array around you; then you select directions, terms of reference, and reference frames, step-by-step (e.g., Levelt, 1989; Taylor & Tversky, 1996). Other judgments, such as counting intersections or restaurants, comparing sizes or distances, estimating time, and more, will lead you to select different information from the scene and organize it in different ways. Many possible objects can be extracted and grouped in many possible ways. Many possible relations can be determined: distance, direction, size, among them. Understanding these relations depends in turn on groupings and orderings, constructs thought imposes on the world.

5.2. Spatial thinking: Perception/action couplings?

Underlying extracting objects, grouping objects, ordering objects comparing objects, groups, orderings and more must be a multitude of processes involving both perception and action. From the classic and profound analyses of Piaget to the most recent treatise on embodied thought comes the insight that both perception and action are involved. Grouping in the mind is undoubtedly connected with grouping in the world, putting similar things together, perhaps into piles, on a surface, and separating different things, an activity that occupies children at play and adults at work. Orderings in the mind are undoubtedly connected with orderings in the world, placing things in order of, say, size or time (e.g., Kirsch, 1995). Taking other perspectives in imagination probably begins with taking other perspectives in the world. Groupings and orderings in the world are easier to make on horizontal surfaces, as they are all around us. Groupings are naturally stretched left-to-right (or vice versa), easier for the hands to arrange and the eyes to see. The same properties of the body and the world make counting easier on horizontal surfaces. What's helpful is to lay things out a single row and to count one by one in a consistent order; the direction of the counting, left to right or right to left, is less consequential. Counting entails two sets of actions, laying out the items, and pointing to each one by one. Both groupings and orderings can additionally capture distance on one or two dimensions, if desired. The perceptual and cognitive processes

involved in disembodied spatial thinking, then, are rooted in concrete actions taken in the world, perception-action couplings. Then both the perception and the action, as noted by many thinkers, among them Piaget and Shepard (2001) are internalized and mirrored in thought, underlying the many phenomena reviewed here and in the other papers in this volume. This analysis also points to the close linkage between space and time, as the perception/action couplings take place step by step in time. That space seems to be fundamental (e.g., Boroditsky, 2001) is probably due to the transient nature of time, which does not allow the inspection and reinspection that space allows.

Spatial thinking is inherently complex and abstract. The abstraction and consequent flexibility in spatial thinking allow it to be extended to further abstractions, to concepts and relations that are not inherently spatial, notably social concepts and relations. At its most abstract, thought is fundamentally concrete, if only because concrete thought itself entails abstraction.

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Flexible foundations of abstract thought: A review and a theory

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Abstract

Since the proposal of conceptual metaphors as the representational means for grounding abstract concepts in concrete sensorio-motor experiences, experimental research about this issue is on the rise. The present paper identifies the problem of flexibility as one of the key questions that remains to receive a satisfactory answer, and proposes a psychologically plausible model that offers such an answer. The model is grounded on basic spatial cognition principles, working memory representations and attentional processes. This framework integrates prior results and licenses several new predictions. Direct test of some of these predictions is provided by two recent studies from our lab. Finally, we discuss the implications of this framework for the issues of the manifestation of conceptual metaphors in behaviour, the acquisition of conceptual metaphors, their cross-cultural variation, and the Symbol Grounding Problem.

1. Introduction

When observing a person talking about an abstract idea, say, a psychology professor describing a particular theory, we can often see that her hands depict in the air the concepts she is mentioning as if they were solid, concrete objects (McNeill, 1992). She might, for example, move her hand upwards as if holding a ball-like object. Simultaneous speech make clear that

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