The spatial foundations of the conceptual system

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Abstract

This article proposes that the representation of concepts in infancy is in the form of spatial image-schemas. A mechanism that simplifies spatial information is described along with a small set of spatial primitives that are sufficient to account for the conceptualizations that preverbal infants use to interpret objects and events. This early system is important to understand because it organizes the adult conceptual system of objects and events and remains its core. With development, the system becomes enriched by language in several ways, and also by means of analogical extension to nonspatial information. Nonspatial bodily information, such as feelings of force and motor activity, is also added, but remains secondary. It becomes associated with spatial representations, but except for its spatial aspects is represented in a more inchoate and less accessible fashion.

Keywords
conceptual primitives, spatial representation, image-schemas, infants

1. The spatial foundations of the conceptual system

For some time I have been concerned about the continuing lack of specification in the literature on image-schemas. In the early days of discussing this form of representation, a certain amount of vagueness was serendipitous, enabling various ideas to be explored. But more than twenty years have passed and instead of the notion becoming more clearly elucidated it

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has come to mean so many different things to different researchers as to seriously undermine its potential value. I am hardly the first person to comment on this problem. For example, Grady (2005) tried to handle the difficulties arising from a surfeit of definitions by proposing to distinguish image-schemas as fundamental units of perceptual experience, such as path, container and force, from non-perceptual schemas, such as cycle, process, and scale (intensity). It may be useful to be even more restrictive than that. Based in part on developmental considerations, a case can be made that for purposes of conceptualizing the world only spatial information is represented in image-schema form and other visual input and bodily information such as feelings of force, balance, and intensity are represented in a different manner or at the least in a much less structured way.

I came to view spatial image-schemas as different from force schemas and others that have been proposed largely because of my work on the foundations of the conceptual system laid down in infancy. But I also noticed that the experimental literature relating image-schemas to conceptual processing is mostly about spatial information, and worried about the reasons for this emphasis. I think we need to distinguish spatial image-schemas from summary representations of other perceptual information, as well as motor and other bodily information, because spatial information is primary in concepts of both objects and events. One reason for the hegemony of spatial information is that a huge number of concepts arise from observing events, and at a minimum these require understanding of objects moving in space. An alternative view to that presented here might be that spatial image-schemas merely have more structure than other image-schemas. In either case, making some distinctions in how different kinds of perceptual and bodily information are represented may be a step forward in understanding both concept formation and thought.

1.1. *The conceptual system is founded on spatial information*

By the term *concept* I refer to the construals or interpretations of objects, relations, and events that enable us to recall the past, to think about absent objects and events, to imagine the future, to make plans, and to solve problems mentally; all of these require at least some conscious processing. They are part of what is usually called declarative knowledge and can be contrasted with perceptual and motor knowledge, usually called procedural knowledge. Although the two kinds of knowledge are deeply entwined there are important differences in the way that they are represented and processed, as well as in accessibility of their contents to conscious awareness (Mandler 2004; Squire 1987).

Although we have little data on the accessibility of concepts in infancy, we do know something about how infants first begin to form concepts. In this article I summarize briefly some of this research and specify a set of spatial primitives that I suggest is both necessary and sufficient to account for the majority—if not all—of the concepts formed during the first year of life. These concepts are important to understand because they are the ontogenetic foundations on which later concepts are built and hence play a major role in determining the organization of the adult conceptual system.

Although it used to be thought that infants did not begin to conceptualize the world until late in what Piaget called the sensorimotor period (i.e. around 18 months), more recently a considerable body of research has shown that the kind of conceptual system that enables recall of the past becomes established at least by 6 to 7 months of age (e.g. Collie and Hayne 1999), and the interpretation of ongoing events even earlier (e.g. Aguiar and Baillargeon 2002). By 8 months the conceptual system lets infants solve simple multistep problems without overt trial and error (Willatts 1997), and by 10 months do spatially based analogical thought (Chen et al. 1997).

For the first 5 to 6 months, because of lack of hand control infants cannot physically act on objects in any effective way. This has at least one major consequence, namely, that their own actions in the early months do not inform the conceptual system. Instead, what matters is what infants pay attention to in the world around them, and that in the first instance is motion through space. Infants are responsive to spatial information from birth and are particularly attracted to moving objects (Slater 1989). At first infants don't have enough foveal information to differentiate objects on the basis of the way they look, but they can differentiate them on the basis of their movements (or lack thereof). Even when acuity is no longer a problem, they attend to whether or not objects move by themselves, whether they interact with other objects and the kinds of paths they take (e.g. Arterberry and Bornstein 2001; Frye et al. 1983; Leslie 1982). Perhaps because of the focus of attention on movement, infants as old as 5 to 7 months often do not attend to the details of what objects look like when they watch events, remembering instead actions or movements in space (Bahrick et al. 2002; Perone et al. 2008). Five-month-olds also are more accurate in encoding the location of objects they watch being hidden than what the objects look like (Newcombe et al. 1999).

Lack of attention to physical detail is one of the reasons why so-called 'basic-level' concepts like dog or cup are not the first kinds of object concepts to be learned. Instead the earliest object concepts tend to be more global—sketchy, superordinate-like notions—such as animal, vehicle, furniture, and container, rather than dog, car, chair, and cup. This has profound consequences for the way the conceptual system becomes organized, because these initial global concepts ground later basic-level concepts—a dog is an animal, a cup is a container. Every time a new animal or container is learned it is understood under the higher-order rubric, thus producing a hierarchically organized conceptual system of objects. This organization is revealed in cases of semantic dementia in adults; lower-level distinctions are lost before higher-level ones, with global membership the longest surviving (Patterson and Hodges 1995).

Finding persuasive tests of conceptual functioning in preverbal infants is challenging, particularly because the nonverbal looking-time tests often used to assess infant's knowledge can sometimes produce data due to online perceptual habituation (Mareschal et al. 2003). One possible test is to show categorization in the face of little or no perceptual similarity among the relevant items. For example, Mandler and McDonough (1993) found categorization of animals contrasted with vehicles in infants as young as 7 months, but lack of categorization of dogs contrasted with rabbits or fish. Similarly, Pauen (2002) found categorization of animals versus furniture at 8 months, but no categorization of chairs versus tables. Mandler and McDonough (1998a) found categorization of furniture contrasted with vehicles at 9 months but no differentiation of tables, chairs and beds.

A more straightforward conceptual test than looking time, albeit one that cannot be used before about 9 months of age, is generalized imitation, in which infants choose what they consider to be acceptable substitutes for an object they saw in an event but that is not currently available for imitation (Mandler and McDonough 1996). By systematically varying the range of substitute objects available and seeing which they will and will not use, we can get preverbal infants to tell us how they have construed an observed event. Using this test we found that differentiation in global concepts occurs gradually. For example, infants conceptually differentiate land animals from birds by 9 months, but do not reliably differentiate dogs from cats, rabbits, or other land animals until sometime in the second half of the second year (Mandler and McDonough 1998b). Infants in our culture are somewhat more advanced in their conceptual differentiation of household artifacts and vehicles, presumably because of their more frequent interaction with these objects. Generalized imitation tests show that a number of common distinctions among household artifacts (for example, the difference between cups and pans) are learned between 14 and 20 months (Mandler and McDonough 1998b, 2000).

Of course, at the same time as infants form concepts they also form perceptual categories based on what objects look like. Indeed, in many ways perceptual categories are more advanced than concepts about them. For example, by 3 months if infants are shown a number of pictures of cats they will perceptually categorize them as different from a picture of a dog (Quinn et al. 1993), but construing dogs, cats, and rabbits as different kinds, as just discussed, takes much longer. Perceptual categorization is part of sensorimotor learning and consists of implicit learning of similarities. Responding to something as having been seen before, as indicated by smiling or learned behavior toward it, is not the same as conceptualizing it. This was, of course, one of Piaget's important insights. Infants live in a rich perceptual world that generates a sense of familiarity as they interact with things, but familiarity with objects and events does not in itself tell us how infants interpret or construe what they are seeing.

Perceptual information must be reduced and also redescribed if it is to become the conceptual knowledge that we use for thought. Concept formation is sometimes said to be a simple derivation from generalization across many instances. But generalization alone is not sufficient. For example, 6-month-olds can perceptually categorize male faces as different from female ones (Fagan and Singer 1979). Since even most adults are unable to bring the difference to conscious awareness, it is clear that the generalization that produces perceptual categories does not by itself produce a conceptual description—our concept of a face does not usually include this information. A selective mechanism is required to redescribe and simplify perceptual information into an accessible conceptual format (Mandler 1992, 2004, 2008). The redescriptions must be both general and simplified in order to characterize a variety of individual instances. The mechanism I have hypothesized to carry out this function, Perceptual Meaning Analysis (PMA), is an attentional mechanism that recodes selected aspects of incoming spatial information into an image-schematic form. This kind of representation creates meanings that can come to consciousness either through imagery or words, thus enabling explicit conceptual knowledge. Needless to say, this does not mean that conceptual processing must always, or even usually, be explicit, only that it can be.

In this view, the first concepts are composed from one or more pieces of spatial information, especially movements in space. I term such spatial components conceptual primitives. Because they are spatial they can have parts, and that in turn implies structure. A classic example is CONTAINER, which is a notion requiring a bounded space with an inside and an outside (Lakoff 1987). The primitive is structured because you can't have an inside without an outside; it is the structure itself that gives the parts meaning. Although the structure can be dissected, it is primitive with respect to the conceptual system.

In this view, it doesn't take a lot of machinery to get concept formation started. There is built-in attention to paths of motion through space and several kinds of spatial relations, such as containment and contact between objects, that are perceptually salient for infants. In addition, there needs to be a mechanism such as PMA that redescribes attended salient information into a simpler, schematic form (which is what I mean by the term *image-schema*). That in turn requires a set of primitives that can be considered as the initial vocabulary of the mechanism. The use of 'primitives' does not imply an axiomatic system, only a set of saliencies that gets concept formation started. (Language can also be used to represent perceptual analyses, but preverbal infants do not have that luxury. It may also be noted that congenitally blind infants process spatial information through touch and sound, but these are inferior sources of spatial information compared to vision. I assume this is why blind infants are cognitively delayed compared to sighted infants before they learn language, which itself is also delayed.) The questions I address here are what these primitives consist of and how many are needed.

1.2. *Spatial primitives and some early concepts constructed from them*

Even restricting the analytic mechanism to spatial information, one might think that a large number of primitives would be required. We process a vast amount of spatial information; think of what is required to give even a very simple description of what a dog looks like. But PMA is activated by attention and in early infancy this is largely determined by movements in space rather than by the details of what things look like. For example, animals can be seen to start motion by themselves and interact with other objects, even from a distance. Young infants are sensitive to whether objects contact others or start by themselves (Leslie 1984; Pauen and Träuble 2009) and also to whether objects interact contingently with them (Frye et al. 1983) or with other objects (Rochat et al. 1997). A conceptualization of animals as self-moving interactors is not a bad core definition, and it is a fundamental meaning that lasts for a lifetime. A similar set of primitive notions describes nonanimals (inanimates) as things that either don't move at all or begin motion only with contact from another object and that do not interact from a distance.

These notions (which are themselves concepts) make use of the following primitives (represented by caps). THING refers to objects, understood as spatially coherent and separate from the rest of the environment. PATH refers to any object's MOTION through space, without regard to speed, direction, or shape of either object or path. START PATH refers to the start of motion along a path through space. CONTACT refers to one object touching another. In addition to combinations of these primitives there is an element of absence of a primitive that combines with PATH, MOTION, or CONTACT, indicating that an object does not move, or does not touch another object. I use a negative sign (-) to express absence, but its status is different in that it does not appear by itself, only in conjunction with the spatial primitives. Thus, animals start motion by themselves (START PATH, -CONTACT), and inanimate things either do not move at all (-PATH) or start to move only when contacted by another object (START PATH, CONTACT). In addition to these primitives, interaction is expressed by LINK, representing a category of contingent actions, such as LINKED PATHS when two objects follow a common path, or back and forth interactions as in turn taking (Mandler 1992). There is a temporal experiential element involved in contingent interactions such as turn taking, in that if the interval between one response and the next is too long, no LINK will be construed. However, experiencing a temporal interval does *not* necessitate that it be conceptualized along with the spatial aspects of the interaction.

Animals can be conceptually differentiated from inanimates via different patterns of these few primitives. Since animals and inanimate things regularly display these patterns, the concepts should be rapidly learned. Rogers and McClelland (2004) showed that it needs no more than a simple connectionist algorithm to learn patterns similar to these that differentiate animals from inanimate things, and then to differentiate kinds within these domains. Subdivision of these domains is one of the ways in which complexity is added to the conceptual system. In some cases differentiation involves combining other primitives with already formed concepts, as in *land* (SURFACE) *animals* versus *air* (UP) *animals*, a subdivision that occurs relatively early in development (Mandler and McDonough 1998a). It is presumably based on the typical location of animals and their paths through space. Other subdivisions, like various mammal kinds, require associating perceptual detail with the higher-level descriptions. These are often later developments dependent on language learning and what the culture teaches, as in the differentiation of *fox* from *dog* (McDonough 2002).

Similar subdivisions occur in the realm of inanimate things. *Vehicle* is an early concept in our culture, and like *animal* it becomes subdivided early into *land vehicle* and *air vehicle* (Mandler and McDonough 1998b). We have little information on the details it includes for infants, but I have suggested that the first concept of *vehicle* consists of something like an outdoor moving container. Locational distinctions are salient to infants, and indoors versus outdoors may be one of the bases of an early concept of *furniture* (indoor inanimate things). However, although a conceptual category of indoor things lasts for a lifetime (Warrington and McCarthy 1987), it hasn't been tested before 16 months of age, at which point infants show a category of highly varied household items that is distinguished from vehicles (Mandler 2004). We also have evidence that 14-month-olds categorize highly varied kitchen and bathroom objects on the basis of their locations (Mandler et al. 1987). These categories have not been tested at earlier ages, but the data strongly suggest a LOCATION primitive. Not only are the indoor-outdoor and kitchen-bathroom distinctions robust enough to be used as the basis for categorizing objects, but the early division of animals into land animals and birds, and vehicles into cars and planes, suggests that location itself is conceptualized. It also is implicated in understanding of *behind*, discussed below. In any case, we do know that *vehicle* and *furniture* are early formed subdivisions of the concept of *inanimate thing* (Mandler and McDonough 1998a). There may also be concepts based on salient animal parts. One that seems likely in the early months is *hand*, a body part that contacts and contains things. Eyes are another possible candidate, but for both these cases, evidence in infancy of conceptualization beyond sensorimotor knowledge is still lacking.

Animal and *inanimate thing* are quite abstract concepts, even though they are among the very first to be formed. Other even more abstract concepts, such as *cause*, in the sense of '*make move*', may begin very early as well. Infants perceptually differentiate self-starting from starting with contact at least by 4 months of age (Leslie 1984), but of course more is needed for a *concept* of caused motion. Hume thought we can't see causality when one object launches another, but we can, or at least we see the transfer of motion from one moving object to another. Our powerful sense of causality when, say, one ball strikes another, comes from the nature of the sensory store that holds visual information and makes us see motion as continuous. Michotte (1963) showed that the timing of the launching events is crucial for our illusion that we see one ball 'make' the other move. We see a causal relation when a conflict exists between two types of continuity cues. Spatial discontinuity says there are two separate objects, whereas continuous motion suggests there is only one. The conflict is resolved by perceiving the sequence as the transfer of motion from one object to the other (White 1988). Since this phenomenon is due to the temporal integration function of the eye, there is no reason to think it does not apply to infants as well as adults. For this kind of perception to be construed conceptually, a MOTION TRANSFER primitive is needed, in which the motion of one object is not only *seen* but also *understood* as moving into another. Notice that the concept of force is not part of this construal. It will become so as infants begin to move themselves around in the world and experience the forceful aspects of motion, but in this view force itself is not a conceptual primitive. I discuss its status further below.

A spatial notion related to *make move* is a path being blocked so that motion abruptly stops. When an object runs into something immoveable there is no motion transfer to be seen, but a sudden END OF PATH. Baillargeon (1986) showed 6 to 8 month olds a car running along a downhill track. Then a block was put on the track and a screen lowered to hide the block from view. When a car was again sent down the track, the infants looked longer if it reappeared from the other side of the screen. We do not know whether infants this young conceptualize this situation; however, to the extent that they do, a BLOCKED PATH primitive is sufficient to describe it. Even infants as young as $2\frac{1}{2}$ months expect that a rolling ball will not go through an object in front of it (Spelke et al. 1992).

An abstract concept that is in evidence beginning around 5 months of age is *goal*. Infants this age are already sensitive to the ends of paths and what happens there (Woodward 1998). A typical goal-directed scenario involves an animal taking a path toward an object and at its end interacting with it. However, 5-month-olds also interpret inanimate objects as goal-directed if they start by themselves (Luo and Baillargeon 2005a), suggesting that the first concept of *goal* is not derived from animals acting but rather from a set of spatial primitives involving START PATH, END OF PATH, and LINK (Mandler 2008). LINK means interaction, and if, for example, a person merely rests the back of their hand on an object, infants do not treat it as a goal (Woodward 1999).

The concept of *goal-directed action*, often referred to as *agency*, seems to derive from two kinds of observation. One is of direct paths, wherein an object starts by itself and goes straight to an object or location rather than taking an (unnecessarily) indirect route. It is plausible that DIRECT PATH is an output of PMA, but the limited evidence we have (Csibra et al. 1999) suggests sensitivity to this kind of goal path only by 9 months. The other kind of observation is of repeated paths ending at the same place, involving equifinal variation). This term refers to changes in the shape of a path (or action at the end of a path) as a function of the specifics of the physical situation, such as a barrier that blocks motion and is jumped over or gone around (Biro and Leslie 2007; Csibra 2008). Responsivity to equifinal variation is likely at first to be limited to paths rather than actions, which require more detailed analysis. This kind of equifinal variation can be characterized as a goal related version of LINKED PATHS, that is, paths that vary contingently upon things between their beginning and end points. Readers familiar with the image-schema of source-path-goal (Lakoff 1987) will notice that I am suggesting here the spatial primitives that structure it: START PATH, LINKED PATHS, END OF PATH, LINK.

This characterization of *goal* concepts and *agency* is adequate to account for 5- to 6-month old infants' interpretations of goal-directed actions. To my knowledge there is no evidence that these early concepts include any attribution of intentionality on the part of agents. They are concepts about behavior rather than the mind. To think 'It's going to that object', and perhaps even thinking 'It's trying to go to that object' does not require a concept of a mental intention. So far as we know, a clear cut understanding of intentions appears at the earliest in the second year (e.g. Tomasello et al. 2005). It may be that what is required for infants to add intentionality to their spatial understanding of goals is to engage extensively in goal-directed behavior themselves (including its successes and failures), a development that first becomes pervasive in the second six months of life. Mapping sensorimotor information about trying into a spatial representation of goal-directed behavior is an important example of the enrichment of early spatial concepts by bodily feelings, discussed further below.

Some of the most interesting early concepts involve spatial relations. It is especially difficult to be sure of these concepts in preverbal children, because most of the data come solely from tests of perceptual categorization. Nevertheless, there is suggestive evidence from the extensive work that has been done on infants' understanding of containment, support, and occlusion. Containment relations, especially events of going into and going out of, strongly attract infant attention, and like occlusion, begin to be learned as early as $2\frac{1}{2}$ months. Extensive work by Baillargeon and her colleagues (e.g. Baillargeon 2004) has shown that early understanding of containment is global rather than detailed. Infants understand *going in* and *going out* before they learn about details such as whether or not a tall object will go into a short container or a wide object into a narrow one.

There is a similar gradual accumulation of details about support relations (Baillargeon, Kotovsky and Needham 1995) although support concepts are less salient than containment for infants (Casasola and Cohen 2002; Choi et al. 1999). The first concept of *support* seems to derive from attention to objects going onto and off of surfaces. There does not appear to be any concept of gravity (even though infants do not expect objects to stay in place in midair; Spelke et al. 1992). In so far as spatial information is being analyzed in support situations, a primitive of ATTACHMENT may be used, in the sense that 3 month olds expect an object to stay even on a vertical surface if it is in contact with it. Over the next months infants gradually learn details about the amount of overlap with a horizontal surface an object needs if it is not to fall (Baillargeon et al. 1995). These data implicate path primitives of INTO CONTAINER, OUT OF CONTAINER, ONTO SURFACE, OFF OF SURFACE, CONTACT, ATTACHMENT (as well as CONTAINER and SURFACE themselves).

It is possible that some of the data on containment and support merely indicate the learning of more detailed perceptual categories with experience. However, there are other data not easily explained without referring to conceptualization. Luo and Baillargeon (2005b) studied 2 to 4 month olds' expectations about objects moving behind occluders. From $2\frac{1}{2}$ to 3 months, infants apparently do not expect to continue to see an object when it moves behind an occluder, even if the occluder is a narrow column and the object is wider. As a result, they show increased attention to such a display. Similarly, when an object goes behind a screen that has a window in it 3-month-olds again show increased attention when the object appears in the window. It isn't until $3\frac{1}{2}$ months that they look longer when such an object does *not* show up in the window. It is difficult to think of a purely perceptual explanation for the 3-month-olds'data, because although infants have experienced people going out of rooms, they have had as many or perhaps even more experiences of objects being only partially hidden as they move behind other objects. The longer looking to what are normal sights suggests that some concept of *moved out of sight* is being violated. Notice that these are not the usual kind of expectation data, where an impossible sight produces longer looking. The response to a normal sight suggests an early example of a concept, perhaps derived from the experience of people going out of sight when they leave a room, broadly (and mistakenly) influencing perceptual expectations about occlusion.

These data suggest that a spatial primitive BEHIND is very early coupled with another output of PMA when an object disappears, represented by the primitive MOVE OUT OF SIGHT. This primitive in some sense is a variant of BLOCKED PATH, since it occurs when a line of sight that connects the infant to an object becomes blocked. It is not just a case of infants forgetting about an object when it disappears. There is evidence that even young infants remember, at least for short periods of time, that hidden objects are still there (McDonough 1999; see also the next paragraph). Regardless of the exact nature of this primitive, object appearance and disappearance attracts infants' attention—think of the game of peekaboo, beloved by 4 month olds.

Three-month-olds are slightly more advanced in their understanding of doors than of windows. That is, they do expect that a little doll shown moving behind a screen that has a door in it will be seen passing by the door before coming out on the other side of the screen and look longer if it does not appear in the doorway (Aguiar and Baillargeon 2002). (Infants probably have more experience in seeing people come to view in doors than passing by windows. Aguiar and Baillargeon consider the relevant variables to be behind versus not-behind, lower-edge discontinuity in an occluder, and height of the occluded object). Interestingly, however, they found that by $3\frac{1}{2}$ months infants did *not* look longer when the doll did not appear in the doorway. They speculated that perhaps the $3\frac{1}{2}$-month-olds inferred that there must be another doll hidden behind the screen. One of the several ways they tested this hypothesis was to show the $3\frac{1}{2}$-month-olds that there was only one doll behind the screen, whereupon the $3\frac{1}{2}$-month-olds now behaved like the 3-month-olds, looking longer at a display in which the doll did not appear in the doorway. This kind of experiment is another example of why it becomes necessary to assume that even very young infants are conceptualizing what they see, not just learning probabilities of occurrence of various sights. Their construals, perhaps especially their misconstruals, are instructive of the kinds of perceptual information that are being used to help form a conceptual system.

There are other relational primitives, such as UP and DOWN, expressing aspects of space that have been less studied in infancy, although they appear to be operative relatively early (Quinn 2003). However, exploration of infants' conceptualization of space is still relatively sparse. For example, we have evidence that infants are learning about tight versus loose containment as early as 5 months (Spelke and Hespos 2002) and have abstracted a general concept of tight (or loose) containment at least by 9 months of age (McDonough et al. 2003). But we do not have enough information to tell us whether a concept such as *tight* is a spatial primitive given directly by PMA. It may be a concept derived from a subdivision of containment; loose containment would be the default case and *tight* would be an addition of BLOCKED PATH to CONTAINER.

Other possible primitives are something like SAME and DIFFERENT as a response to spatial patterns. We do not yet know how early a concept of *same* or *different* appears in development, although infants are clearly responsive to whether spatial displays are the same or not. LINKED PATHS, for example, depends on such a perception, as do categorization and subitizing small numbers. Indeed, forming a concept of *animal* as a self-starting interactor depends on extracting the same information from perception of a variety of different animals' behavior. But once again, it is important to note that the perceptions used in forming concepts are not necessarily concepts themselves. Perceiving two patterns as alike or different does not involve the same kind of simplification of information that

PMA engages in and also occurs in other modalities than space. It seems likely, therefore, that they are independently generated innate reactions to patterns of information, and so I do not include them in the suggested list of spatial primitives. At some developmental point, the processing of patterns as same or different (which as a kind of procedural processing begins quite early) clearly does become conceptualized, but we have essentially no information as to how or when that happens.

The primitives I have discussed are listed here:

PATH
START PATH
END OF PATH
BLOCKED PATH
LINKED PATHS
DIRECT PATH?
MOTION
MOTION TRANSFER
MOVE OUT OF SIGHT
CONTACT
ATTACHMENT
LINK
CONTAINER
INTO CONTAINER
OUT-OF CONTAINER
SURFACE
ONTO SURFACE
OFF-OF SURFACE
THING
LOCATION
UP
DOWN
BEHIND

Either singly or in combination these spatial primitives go far toward founding a conceptual system. It seems likely that there are others, such as DIRECT PATH, given here a question mark, and a few other spatial relations such as ACROSS OR NEXT-TO, but not many more should be needed: I have suggested that something like 25 spatial primitives are enough to characterize the conceptual system of infants in the first year of life (Mandler 2008). These primitives are sufficient for infants to form initial concepts of animals and inanimate things. They are also sufficient for infants to conceptualize the paths and spatial relations that in the most general sense characterize people's interactions with objects and with other people. Needless to say, these primitives do not represent all that infants know. They are learning what different kinds of things look like, to differentiate people from other animals (Pauen 2000), to differentiate one animal from another (Quinn et al. 1993), what cups and pans look like, and so forth. What is under discussion is how infants interpret these things and the events they take part in, even as they are learning to perceptually categorize them. For example, they can learn to tell cups from pans even though they construe both as containers. Thus, my argument is that a relatively small number of spatial primitives are sufficient to ground the conceptual system.

1.3. *Enriching the spatial conceptual base*

How does more powerful thought develop from such simple beginnings? In general, there are four main ways that conceptual expansion or enrichment takes place: subdivision of concepts, language use of several types, analogical extension to nonspatial domains, and associating bodily information with the spatial base. (By bodily information, I mean nonspatial sensory information that comes from vision, touch, taste, as well as motor activity and autonomic activation. Auditory information may be a special case, not considered here other than to suggest its conceptual development differs when it is structured rather than unstructured.)

I've already mentioned that subdivision of existing global concepts can occur simply by including other primitives, as in 'UP *animal*.' These subdivisions can occur quite early, based on the infant's attentive analysis. Another way to subdivide global concepts is via language, which directs attention to neglected details, such as long rabbit ears or tiger stripes. Perceptual Meaning Analysis allows the conceptualization of spatial distinctions whenever analysis of perceptual information is carried out. Adults' use of a consistent distinction within a context that the child already understands globally should direct the child's attentive analysis, enabling the discovery of the overlooked particulars that the language is specifying. For example, as early as 6 months, infants begin to use labels provided by adults to subdivide animals (Fulkerson and Waxman 2007). In some cases, infants may already have formed the relevant perceptual schemas and the new labels provide a convenient shorthand for the new concepts. Even as adults many of our 'basic-level' animal concepts contain not much more than a label attached to a crude physical description (e.g. 4 legs, long tail) with some bits of other information such as location or diet that differentiates one from another. Here again, the perceptual schemas that enable recognition are more detailed than the conceptualizations.

Another important function of language is to help expand the conceptual system beyond spatial information. Language helps categorize unstructured sensory information for which there are no primitives, such as colors, tastes, and emotions. Infants experience all of these but to my knowledge there is no evidence for conceptualization of them before language. For example, any particular color concept may consist of no more than a label that points to a particular type of experience (Roberson et al. 2005). It is possible that concepts involving unstructured sensory information require language to be thought about at all. At least to some extent they remain that way—the concepts consisting merely of words referring to otherwise unanalyzed perceptual experiences. Still another language contribution, and one of great importance, is providing an amodal symbol system that will ultimately allow conceptualization of truly abstract notions such as found in mathematics and the sciences.

The third main source of concept enrichment, especially useful for constructing concepts that have little or no perceptual basis, is the analogical extension of spatially-based concepts into nonspatial realms. Analogical learning is in evidence even in infants, who before a year of age begin to show analogical transfer from one problem to another (Chen et al. 1997), and it remains a major source of conceptual growth throughout life (Gentner 2003; Goswami 1992).

A classic example of using spatial knowledge to conceptualize a nonspatial domain is *time*. The spatial underpinning of this concept has long been acknowledged by linguists and psychologists (e.g. Clark 1973; Guyau 1890/1988). The passage of time is phenomenally experienced (see Evans 2003 for discussion), but feeling is not the same as conceptualizing. It is conceptualization that makes use of spatial metaphor, such as a long time, the passage of time, going back in time, time approaching, and so forth (Lakoff and Johnson 1999). The basis of understanding time in terms of space is not just linguistic; spatial information primes temporal interpretation (Boroditsky 2000) and people can't ignore spatial information when making judgments about duration (Casasanto and Boroditsky (2008). Of course, we can tell the difference between a unidimensional spatial path and a unidimensional temporal duration, but the latter is a feeling that needs help from metaphor to be conceptualized. In short, our concept of time is a spatial concept coupled with an unanalyzed sensory experience of duration. We can speculate about possible measures of duration, for example in terms of the ordering of events, but these are intellectual exercises, not part of our ordinary understanding of time. As for infants, although they experience duration it is not clear that there is any awareness of it. An interesting question, albeit one that cannot be answered at present, is whether the phenomenological experience of duration is developmentally prior to conceptualizing time. It is possible that children learn words that apply to time, such as long and short, before they become aware of the bodily feeling of time passing.

The discussion of *time* borders on the fourth, and very important, method of enrichment, namely, mapping bodily information into the spatial base. This process, different from merely learning words to refer to feelings, surely adds enrichment, although perhaps in a different way than envisaged by many researchers working within an embodiment framework. For example, although many researchers assume that there are force image-schemas, it is equally possible that our concept of *force* depends on spatial image-schemas in a way like that of *time*. As discussed earlier, MOTION TRANSFER (the spatial representation of motion being transferred into an object) is sufficient to initiate a concept of force. Six-month-olds already have a concept of caused motion without yet having enough of the experiences needed to add a dynamic (as opposed to purely kinetic) aspect to the concept. In this view, *force* is a spatial concept that becomes enriched by becoming associated with certain sensorimotor experiences. For example, you can attend to the 'umph' you feel when experiencing a BLOCKED PATH, as when you push against something immoveable. This kind of experience begins to be common in the second six months of life, when infants may struggle in their parents' arms or try to push something away. When the feeling of pressure becomes associated with a BLOCKED PATH it adds a crude dynamic aspect to the spatial primitive. In short, a conceptual description becomes augmented by a bodily feeling that is not itself conceptually described, perhaps not even as greater or lesser force. The result is a spatial image-schema that can activate a bodily feeling, although usually in a nonperceptible way. In a distributed processing system motor activation may accompany or be part of a simulation, but that does not require a force image-schema.

Of course, the structure of forceful interactions can be dissected, as in Talmy's (1988) force-dynamics analysis. Still, it is interesting to contrast the spatial and forceful components he used. Basically the patterns he described consist of three interacting tendencies: an object either moves or not (a spatial variable), it either does the moving or receives it (another spatial variable), and it is either stronger or weaker than the other object. The spatial components were represented spatially, but so was the forceful component and no further analysis was given to it. I believe the reason for that is because the way our conceptual system is constructed makes it extremely difficult to do so. Much of the time we use the shortcut of language, but even when we think about force or observe a forceful interaction so dramatic that it calls forth an empathetic response, at most we experience a tightening of the stomach or other muscles. Sometimes the spatial representation may be accompanied by a bodily reaction of which we are not aware, but in either case the bodily reaction itself is not sufficient to be called an image-schema. It can only supplement a spatial representation of the event.

The same argument can be applied to other nonspatial image-schemas that have been proposed, such as balance and resistance (Gibbs 2005; Johnson 1987). There is no doubt that we have feelings of balance and can form images of balancing (as in imagining a person walking on a high wire). But it is not clear exactly what is added to the spatial representation involved in such imagery. We can also represent balance by a back and forth movement of the body or hands, but the feel of the movement is secondary to its spatial aspect. The bodily feeling adds richness to the concept but is not its core. The notion of resistance has the same problem as force. A bodily feeling may be activated, but it is unstructured and vague in comparison with the spatial aspects. It is probably for this reason that the embodiment literature depends so heavily on spatial, as opposed to nonspatial, findings.

1.4. *Spatial image-schemas versus bodily representations*

Based on the considerations just discussed, I propose that we limit the term *image-schema* to representations of spatial information (both static and moving) and consider the possibility that nonspatial bodily representations function in different ways. First, spatial representations, possibly with one or two supplements such as *see* and *same*, are sufficient to found the conceptual system. Considerable conceptual headway can be made without including other visual properties of objects, force dynamics, or personal experience of carrying out actions. In this view not only can a human conceptual system exist without representing bodily information, it actually begins this way. Second, spatial representations are considerably more structured than are bodily representations, which tend to be unidimensional or even cruder, making spatial representations more useful for inference and, importantly, making information about absent events potentially recallable. Third, spatial information is more often used for metaphor and analogy than bodily information, probably in part because it is better structured. Fourth, spatial representations are automatically activated during comprehension, even when the spatial implications are abstract, such as in verbs like *respect* and *succeed* (Richardson et al. 2003). Fifth, mental simulations used to understand or imagine events always require a spatial component, but not necessarily a bodily one.

Unfortunately, aside from simulation in the form of conscious imagery, exactly what simulation involves has not yet been well specified. To my knowledge, the original formulation by Barsalou (1999), which presented an extensive but necessarily schematic account has, aside from some experimental support for its existence (e.g. Pecher et al. 2003), not been greatly amplified. At most, there have been attempts to locate simulation in modality-specific areas of the brain. However, the literature showing activation of motor areas during comprehension, for example, (e.g. Pulvermüller 2005) may merely reflect associated bodily feelings that are supplementary to the spatial simulation taking place rather than being central to the psychological processes that are essential for comprehension.

It is hardly surprising that motor areas are activated when thinking about or imagining carrying out an action, but activation is not a synonym for simulation. In this regard, metaphorical action language such as 'grasping a concept' apparently does not activate brain motor areas more than similarly abstract but non-motor based language (Ruschemeyer et al. 2007).

It has been suggested that simulation is context-specific rather than general (Barsalou et al. 2003). Regardless of what might be true for adults, it is unlikely that the conceptual understanding of infants involves context-specific simulation. Even though context affects sensorimotor learning in infants, the attentive processing required for concept formation does not take in enough detail for their conceptual representations of objects and events to be context-specific. As described above, early understanding of objects and events is global in nature. Even older infants still conceptualize events broadly, as shown by the generalized imitation data. When a 14-month-old watches a dog being given a drink from a cup, if the simulation being run underlies a conceptual interpretation of the event, it consists of a movement of a *container* to an *animal* and not movement of a *cup* to a *dog*. Combinations of spatial image-schemas can account for such performance; it is less clear how context-specific simulation would. Of course, simulations might make use of current perceptual information even for young infants, but that leaves a serious problem as to how a context-specific simulation results in a more global conceptual understanding.

Some researchers also claim that even recognizing and categorizing actions requires motor simulation (e.g. Gallese and Lakoff 2005). However, infants can categorize actions on the basis of spatial movement before they are able to perform the actions themselves. For example, as mentioned earlier, infants categorize animals on the basis of biological motion by 3 months of age (Arterberry and Bornstein 2001), a good many months before they have acquired the motor experience said to be required for simulation of such motion (not to mention that 4-legged animals move very differently from 2-legged ones). Adolescents with congenital motor disorders recognize biological motion in spite of never having experienced it in their own actions and thus not having any relevant actions to simulate (Pavlova et al. 2003). Studies of apraxia, in which patients no longer know how to perform the correct actions to use with various objects, nevertheless recognize the objects and the correct actions carried out on them by others (Hodges et al. 1999; Negri et al. 2007).

Considerations such as these suggest that a conceptual understanding of objects and events can be formed and maintained through perceptual observation of spatial information alone. These may be understood by simulation, but it would be spatial simulation rather than motor, and as just discussed, would often need to be general rather than context-specific. Although normal adult processing of action is often multimodal, personal experience of an action is not necessary in order to understand it. Needless to say, this point of view does not deny that action concepts are enriched by experience of carrying them out; it only says that motor knowledge is not essential to conceptualizing them.

Ultimately, the most important bodily functions required to understand the full adult conceptual system are conscious mental states. More important than feelings of force or balance or intensity are attention to and conceptualization of one's own desires, goals, emotions, and thoughts, since these are necessary to fully understand the social world. Social and emotional responses begin from birth, but they are much less observable or analyzable than objects and events. It may be that the most important accomplishment of mapping sensorimotor information into a spatial conceptual base is to enable concepts about the mind. One example was mentioned earlier, of associating feelings of wanting or trying to spatially based concepts of *goal* and *goal-directed behavior*. The sensorimotor feelings of wanting or trying are themselves unstructured and difficult to observe and analyze, but spatial image-schemas are available to stand for them and thus to enable thought about them. More difficult are mental concepts such as *knowing*. Although knowing is based on experience with seeing and not seeing, there are no obvious spatial image-schemas to stand for and help organize this otherwise unspecified mental feeling. The long slow development of a theory of mind suggests that mapping the vague sensory feelings involved in mental states of knowing and not knowing into a spatially-based conceptual system is difficult, and even more than concepts of intentionality may require help from language.

1.5. *Conclusion*

I have presented a theory of how the considerable conceptual system that develops over the course of roughly the first year of life can be achieved through spatial information alone. Certain kinds of spatial information (especially motion through space) are highly salient to young infants, thus attracting the attention needed for concept formation. The concepts of objects, events, and relations derived from simple redescriptions of spatial information create an adequate base for first interpretations of the world and for beginning to learn language as well (Mandler 2005). The spatial image-schemas representing these concepts are well structured in a way that makes it possible to retrieve information about absent events and enables the inferences that are important in expanding the conceptual system. Although other sources of information will contribute to concept formation (such as one's own feelings), spatial image-schemas ground the system and form the conceptual core to which bodily information, including information about mental states, gets added. What results are concepts represented by spatial image-schemas, some of which are closely coupled with associated bodily feelings that are not themselves conceptualized, or at best only crudely so.

Spatial information is readily available even to very young infants; it is the most continuous, observable, and structured information about the world that they have. Bodily feelings are not only more intermittent, they are often unstructured, and even for adults difficult to describe. They add experiential richness to action and event concepts, but that is not the function that I believe image-schemas are used for, which is to put information in a form that can stand for (symbolize, if you will) observations about the world, thus enabling both thought and language understanding. I sympathize with Johnson (2005) saying that image-schemas leave out something of great importance, namely, the felt qualities of situations. They do, but that may be too much to ask of them. We may have to rely on literature and art to help us conceptualize what is usually only felt. Even when felt qualities accompany a simulation, that does not make the information conceptual and accessible for conscious thought.

The present account necessarily has speculative parts. There is by now a moderate amount of evidence about the preverbal development of knowledge about objects and the spatial aspects of events. Yet it is often difficult to tell implicit perceptual knowledge from potentially explicit conceptual knowledge. In many of the examples I have discussed, there is adequate evidence of concept formation as opposed to mere perceptual learning, but usually not enough data to be entirely sure of the representations that infants are using in the tasks set for them. This is a crucial area of research that needs to be intensively explored and modeled if we are to achieve a mature understanding of how the concepts needed for thought, recollection, and language are formed and how they interact with sensorimotor knowledge.

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