The cognitive psychological reality of image schemas and their transformations

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Abstract

One of the important theoretical ideas in cognitive semantics is that image schemas and their transformations provide part of the foundation for thought, reasoning, and imagination. Image schemas are different patterns of recurring bodily experiences that emerge throughout sensorimotor activity and from our perceptual understanding of actions and events in the world. Our aim in this paper is to discuss some of the empirical evidence from psycholinguistics, cognitive psychology, and developmental psychology that is consistent with the idea that image schemas and their transformations play important roles in human cognition. This experimental research was not conducted and has not generally been considered in terms of the cognitive linguistic ideas on image schemas. However, a large body of research can be interpreted as supporting the claim that image schemas are indeed psychologically real and function in many aspects of how people process linguistic and nonlinguistic information. Our review suggests possible ways of integrating this research with the findings on linguistic structure and meaning in cognitive semantics.

One of the important claims of cognitive semantics is that much of our knowledge is not static, propositional and sentential, but is grounded in and structured by various patterns of our perceptual interactions, bodily actions, and manipulations of objects (Johnson 1987, 1993; Lakoff 1987, 1990; Talmy 1988). These patterns are experiential gestalts, called *image schemas*, that emerge throughout sensorimotor activity as we manipulate objects, orient ourselves spatially and temporally, and direct our perceptual focus for various purposes (Johnson 1991).

Studies in cognitive linguistics suggest that over two dozen different image schemas and several image schema transformations appear regularly in people's everyday thinking, reasoning, and imagination (Johnson

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1987; Lakoff 1987). Among these are the schematic structures of CONTAINER, BALANCE, SOURCE-PATH-GOAL, PATH, CYCLE, ATTRACTION, CENTER-PERIPHERY, and LINK. These image schemas cover a wide range of experiential structures that are pervasive in experience, have internal structure, and can be metaphorically elaborated to provide for our understanding of more abstract domains. For example, cognitive linguistic research has examined how image schemas are used to create grammatical forms (Langacker 1987, 1991), to represent the underlying meaning that relates the seemingly disparate senses of prepositions (Brugman and Lakoff 1988; Vandeloise 1993), to motivate verb-particle constructions, such as those focusing on *up* and *out* (Lindner 1983), adverbs, such as *very* (Brugman 1984), certain verbs, such as *take* (Norvig and Lakoff 1987), as well as to explain the many kinds of cognitive relationships that can form the basis of the extension of a category such as Japanese *hon* (Lakoff 1987). More recent investigations from linguistics and philosophy examined the role that image schemas have in motivating abstract metaphorical concepts, such as causation, death, and morality (Johnson 1993; Lakoff 1990; Lakoff and Turner 1989; Turner 1991).

Although these studies provide important evidence on image schemas in everyday thought and linguistic understanding, the question remains as to whether there exists independent empirical evidence on the psychological reality of image schemas. Our aim in this paper is to describe some of the findings from psycholinguistics, cognitive psychology, and developmental psychology that, in our view, support the claims of cognitive semantics about image schemas and their transformations.

There are two important reasons for considering this psychological evidence. First, cognitive linguists, following the cognitive commitment to construct theories that are consistent with what is known about the mind and brain (Lakoff 1990, 1993), should be aware of the experimental findings from neighboring disciplines, especially data that bear on the possible connections between perception, thought, and language. Second, psychologists are sometimes skeptical about theoretical notions from linguistics that are primarily based on an individual analyst's intuitions about linguistic structure and behavior. One of the main reasons for conducting experiments with large groups of people is to minimize the uncertainty in making inferences about thought and behavior in whole populations of people.

We do not entirely agree with the skepticism of psychologists about the theoretical claims of cognitive linguists (e.g., Kennedy and Vervaeke 1993). Yet we think there exist different kinds of empirical evidence from psychology that both psychologists and cognitive linguists should be aware of regarding the importance of image schemas in ordinary cognitive functioning. This paper describes some of this evidence. We begin by first elaborating the notion of image schemas and how they are transformed. We then review work from psycholinguistics that has explicitly examined how image schemas motivate people's understanding of word meaning. The next section of the paper describes work from cognitive psychology that seems quite consistent with claims for the importance of image schemas in everyday cognition. We then review work from developmental psychology that also supports the cognitive reality of image schemas. The final section discusses the significance of the different work from psychology for future studies in cognitive linguistics.

Image schemas and their transformations

Image schemas can generally be defined as dynamic analog representations of spatial relations and movements in space. Even though image schemas are derived from perceptual and motor processes, they are not themselves sensorimotor processes. Instead, image schemas are "primary means by which we construct or constitute order and are not mere passive receptacles into which experience is poured" (Johnson 1987: 30). In this way, image schemas are different from the notion of schemata traditionally used in cognitive science, which are abstract conceptual and propositional event structures (see Rumelhart 1980). By contrast, image schemas are imaginative and nonpropositional in nature and operate as organizing structures of experience at the level of bodily perception and movement. Image schemas exist across all perceptual modalities, something that must hold for there to be any sensorimotor coordination in our experience. As such, image schemas are at once visual, auditory, kinesthetic, and tactile.

We can illustrate what is meant by the notion of image schema, and how its internal structure is projected onto new domain via metaphor, by considering the BALANCE schema (Johnson 1987). The idea of balance is something that is learned "with our bodies and not by grasping a set of rules" (Johnson, 1987: 74). Balancing is such a pervasive part of our bodily experience that we are seldom aware of its presence in everyday life. We come to know the meaning of balance through the closely related experiences of bodily equilibrium or loss of equilibrium. For example, a baby stands, wobbles, and drops to the floor. It tries again and again, as it learns how to maintain a balanced erect posture. A young boy struggles to stay up on a two-wheeled bicycle as he learns to keep his balance while riding down the street. Each of us has experienced occasions when we have too much acid in our stomachs, when our hands get cold, our heads feel too hot, our bladders feel distended, our sinuses become swollen, and our mouths feel dry. In these and numerous other ways we learn the meanings of lack of balance or equilibrium. We respond to imbalance and disequilibrium by warming our hands, giving moisture to our mouths, draining our bladders, and so forth until we feel balanced once again. Our BALANCE image schema emerges, then, through our experiences of bodily equilibriums and disequilibriums and of maintaining our bodily systems and functions in states of equilibrium. We refer to these recurring bodily experiences as *image schemas* to emphasize means of structuring particular experiences schematically so that we can give order and connectedness to our perceptions and conceptions (Johnson 1987).

One of the most interesting things about image schemas is that they motivate important aspects of how we think, reason, and imagine. The same image schema can be instantiated in many different kinds of domains because the internal structure of a single schema can be metaphorically understood. Our BALANCE image schema, to continue with this example, is metaphorically elaborated in a large number of abstract domains of experience (e.g., psychological states, legal relationships, formal systems) (Johnson 1991). In the cases of bodily and visual balance, there seems to be one basic scheme consisting of a point or axis around which forces and weights must be distributed so that they counteract or balance off one another. Our experience of bodily balance and the perception of balance is connected to our understanding of balanced personalities, balanced views, balanced systems, balanced equilibrium, the balance of power, the balance of justice, and so on. In each of these examples, the mental or the abstract concept of balance is understood and experienced in terms of our physical understanding of balance. Image schemas have internal logic or structure that determine the roles these schemas can play in structuring various concepts and in patterns of reasoning. It is not the case that a large number of unrelated concepts (for the systematic, psychological, moral, legal, and mathematical domains) all just happen to make use of the same word *balance* and related terms (Johnson 1991). Rather, we use the same word for all these domains because they are structurally related by the same sort of underlying image schemas, and are metaphorically elaborated from them.

Image schemas do not simply exist as single entities, but are often linked together to form very natural relationships through different *image schema transformations*. Image schema transformations have been shown to play a special role in linking perception and reason. Among the most important image schema transformations are (Lakoff 1987: 443):

(a) *Path-focus to end-point focus*: Follow, in imagination, the path of a moving object, and then focus on the point where it comes to rest, or where it will come to rest.

(b) *Multiplex to mass*: Imagine a group of several objects. Move away (in your mind) from the group until the cluster of individuals start to become a single homogeneous mass. Now move back down to the point where the mass turns once again into a cluster.
(c) *Following a trajectory*: As we perceive a continuously moving object, we can mentally trace the path it has traversed or the trajectory it is about to traverse.
(d) *Superimposition*: Imagine a large sphere and a small cube. Increase the size of the cube until the sphere can fit inside it. Now reduce the size of the cube and put it within the sphere.

Each image schema transformation reflects important aspects of our visual, auditory, or kinesthetic bodily experience. To illustrate, consider how these transformations might apply to our earlier example of the image schema for balance or equilibrium. A situation where several of these transformations interact with the balance image schema is that of handling a group of animals. In order to successfully control and navigate a large number of animals, cattle or sheep perhaps, one needs to maintain the cohesiveness of the group. If a portion of the herd begins to drift apart from the whole, an instance of the Multiplex to mass transformation, equilibrium has been lost and action must be taken to restore it. Such a corrective action requires that the path of the drifters be ascertained, following a trajectory, and that their destination be determined and "headed off", path-focus to end-point focus. There are many examples like this that illustrate the role of image schemas and different transformations in structuring our understanding of real-world phenomena. We will consider other instances of image schema transformations as demonstrated in several studies from cognitive and developmental psychology. But we will first consider some of the experimental evidence on the role of image schemas in motivating people's understanding of word meaning.

Psycholinguistics and image schemas

Consider the word *stand* in the following sentences: *Please stand at attention. He wouldn't stand for such treatment. The clock stands on the mantle. The law still stands. He stands six-foot five. The part stands for the whole* and *She had a one-night stand with a stranger*. These sentences represent just a few of the many senses of *stand* that are common in everyday speech and writing. Some of these senses refer to the physical act of standing (e.g., *Please stand at attention, The clock stands on the mantle, He stands six-foot five*), while others have nonphysical, perhaps figurative, interpretations (e.g., *We stood accused of the crime, The part* *stands for the whole, He wouldn't stand for such treatment*). What are the principles that relate the meanings of polysemous words? For instance, what relates the different physical and nonphysical senses of *stand* in the examples noted above?

Some linguists in recent years have argued that many polysemous words resist being defined by a general, abstract, core sense (Brugman and Lakoff 1988; Fillmore 1982; Geeraerts 1993; Sweetser 1986). Cognitive linguists have suggested that the meanings of polysemous words can be characterized by metaphor, metonymy, and different kinds of image schemas (Lakoff 1987; Johnson 1987; Sweetser 1990). Under this view, the lexical organization of polysemous words is not a repository of random, idiosyncratic information, but is structured by general cognitive principles that are systematic and recurrent throughout the lexicon. Most important, perhaps, is the claim that these principles arise from our phenomenological, embodied experience. One possibility is that bodily experience partly motivates people's intuitions as to why different senses of *stand* have the meanings they do.

Gibbs et al. (1994) attempted to experimentally show that the different senses of the polysemous word *stand* are motivated by different image schemas that arise from our bodily experience of standing. Their general aim was to empirically demonstrate that the meanings of the polysemous word *stand* are not arbitrary for native speakers, but are motivated by people's recurring bodily experiences in the real world.

As a first step toward understanding how image schemas partly motivate the meanings of the polysemous word *stand*, a preliminary experiment sought to determine which image schemas best reflect people's recurring bodily experiences of standing. A group of participants were guided through a brief set of bodily exercises to get them to consciously think about their own physical experience of standing. For instance, participants were asked to stand up, to move around, bend over, to crunch, and to stretch out on their tip-toes. Having people actually engage in these bodily experiences facilitates participants' intuitive understandings of how their experience of standing related to many different possible image schemas. After this brief standing exercise, participants then read brief descriptions of 12 different image schemas that might possibly have some relationship to the experience of physical standing (e.g., VERTICALITY, BALANCE, RESISTANCE, ENABLEMENT, CENTER-PERIPHERY, LINKAGE). Finally, the participants rated the degree of relatedness of each image schema to their own embodied experience of standing. The results of this first study showed that five image schemas are primary to people's bodily experiences of standing (i.e., BALANCE, VERTICALITY, CENTER-PERIPHERY, RESISTANCE, and LINKAGE).

A second experiment investigated people's judgements of similarity for different senses of *stand*. The participants sorted 35 different senses of *stand* into five groups based on their similarity of meaning. An analysis of these groups revealed that participants did not sort physical senses of *stand* separately from the nonphysical or figurative senses. For example, the physical idea of standing in to *stand at attention* was often grouped with the metaphorical senses of *stand* in *let the issue stand* and *to stand the test of time*.

The third experiment in this series examined the relationship between the five image schemas for the physical experience of standing and the various senses of *stand* studied in Experiment 2. Once again, participants were first asked to stand up and focus on different aspects of their bodily experience of standing. As they did this, the participants were presented with verbal descriptions of the five image schemas BALANCE, VERTICALITY, CENTER-PERIPHERY, RESISTANCE, and LINKAGE. Afterwards, the participants were given a list of 32 senses of *stand* and asked to rate the degree of relatedness between each sense and the five image schemas.

The rating data from this third study allowed Gibbs et al. (1994) to construct an image schema profile for each of the 32 uses of *stand*. Several interesting similarities emerged in the image schema profiles for some of the 32 senses of *stand*. For example, *it stands to reason* and *as the matter now stands* both have the same image schema profile (in their rank-order of importance) of LINKAGE—BALANCE—CENTER/PERIPHERY—RESISTANCE—VERTICALITY. The expressions *don't stand for such treatment* and *to stand against great odds* are both characterized by the image schema profile RESISTANCE—CENTER/PERIPHERY—LINKAGE—BALANCE—VERTICALITY.

The primary goal of this study, though, was to assess whether the senses of *stand* seen as being similar in meaning in the second experiment were reliably predictable from the image schema profiles obtained in this study. Statistical analyses showed that knowing the image schema profiles for different senses of *stand* allowed us to predict 79% of all the groupings of *stand* in Experiment 2. These data provide very strong support for the hypothesis that people's understandings of the meanings of *stand* are partly motivated by image schemas that arise from their bodily experiences of standing. A fourth study showed that participants' sortings of *stand* in different groups cannot be explained simply in terms of their understanding of the contexts in which these words appeared. Thus, people did not sort phrases, such as *don't stand for such treatment* and *to stand against great odds*, because these phrases refer to the same types of situations. Instead, it appears that people's similarity judgments are best attributed to their tacit understanding of how different patterns of image schemas motivate different uses of the polysemous word *stand*.

This psycholinguistic research has demonstrated that people make sense of different uses of *stand* because of their tacit understanding of several image schemas that arise partly from the ordinary bodily experience of standing. These image schemas, the most important of which are BALANCE, VERTICALITY, CENTER-PERIPHERY, RESISTANCE and LINKAGE, not only produce the grounding for many physical senses of *stand* (e.g., *he stands six-foot nine, stand in the way*, and *stand at attention*), but also underlie people's understanding of complex, metaphorical uses (e.g., *the part stands for the whole, as the matter now stands*, and *the engine can't stand the constant wear*). People perceive different senses of *stand* as similar in meaning partly on the basis of the underlying image schema profile for each use of the word in context.

This conclusion about the meanings of the word *stand* does not imply that people judge similarity of meaning between two senses of a word only on the basis of image schemas. Many aspects of word meaning that have little to do directly with image schemas certainly play some role in people's understanding of word meaning and their judgments of similarity of meaning for different senses of a polysemous word. At the same time, this experimental research does not imply that people automatically access some specific pattern of image schemas each time they encounter a particular use of a word. The main conclusion, though, from the experimental work is that people tacitly recognize some connection between these schematic bodily experiences and different aspects of linguistic meaning, including meanings that are highly abstract and/or metaphorical.

The psycholinguistic research on *stand* is, as far as we know, the only empirical work in psychology that has explicitly set out to investigate the possible role of image schemas in perception, thought, or language use. This work should be of interest to skeptics of cognitive linguistic ideas on image schemas because the methodology employed in these studies allowed for the independent assessment of bodily experience apart from any analysis of how the body might motivate linguistic expressions. Psychologists often contend that cognitive linguistic research suffers from circular reasoning in that it starts with an analysis of language to infer something about the mind and body which in turn motivates different aspects of linguistic structure and behavior. By independently assessing bodily experience of standing beforehand, Gibbs et al. (1994) were able to make specific predictions about people's understanding of different uses of *stand*. Making specific experimental predictions, which can be falsified, about people's linguistic behavior is an essential ingredient for psychologists if they are to accept the psychological reality of any hypothetical construct such as image schemas.

Cognitive psychology and image schemas

The possible relevance of cognitive psychology research to image schemas was first noted by Johnson (1987) and Lakoff (1987). They both described several studies on mental imagery that supported the idea that image schemas and their transformations play an important role in cognitive functioning. We will briefly consider these studies as well as describing several other lines of research on nonlinguistic information processing that are connected with the cognitive psychological reality of image schemas and their transformations.

One topic that might be especially relevant to image schemas and their transformations is the connection between imagery and perception. Research in imagery is of central importance to the long-standing debate in cognitive science concerning whether the human mind employs both propositional and analog representations. What does the study of mental imagery tell us about image schemas and their transformations?

The early research on mental imagery focused on the idea of selective interference. Consider first a classic study by Brooks (1968). Participants were presented with figures, such as the letter F, or sentences that were then taken away. Afterwards, the participants were asked to scan their mental images of the figures to answer specific questions. For the sentences, participants had to recall each word in the sentence sequentially and indicate if the word was a noun or not. For the line diagrams, which were in the form of block letters, participants had to imagine a particular corner of the diagram, and then proceed around the perimeter of the diagram and indicate if each corner of the letter that they imagined was an extreme outside corner or not. On both kinds of recall, participants were instructed to respond either verbally, by saying "yes" or "no", or visually, by pointing to a sheet with "yes" and "no" printed on it. Brooks found that the type of recall and the method of reporting conflicted if they were in the same modality. Participants were slower to respond visually than verbally when recalling the line diagram. Participants were also slower when responding verbally than visually when recalling the sentences. In general, imagery led to a drop in performance in tasks that used related processes. Other studies by Segal and Fusella (1970) showed that visual and auditory imagery can selectively interfere with the detection of signals from the same modality. Johnson (1987) suggested that the data from Brooks' study provided evidence for image schemas in that people seemed able to access certain modes of cognition, either recall of verbal information or visual imagery, through multiple channels, such as kinesthetic or verbal report.

Johnson (1987) and Lakoff (1987) also argued that several classic studies on mental rotation of images provide evidence in support of image schemas and their transformations. For example, participants in one study were presented with two-dimensional drawings of pairs of three-dimensional objects. The participants' task was to determine whether the two represented objects were identical except for orientation (Shepard and Metzler 1971). Some of the figures required rotation solely within the picture plane, while others required rotation in depth ("into" the page). The general result was that, whether for two- or three-dimensional rotations, participants seem to rotate the objects mentally at a fixed rate of approximately 60 degrees per second. Further experiments seemed to confirm this phenomenon (Cooper and Shepard 1982). Control studies demonstrate that mental imagery effects can not be easily explained in terms of verbal or other analytic strategies that might have been based on the initial description of a visual pattern (Bethell-Fox and Shepard 1988; Cooper and Podgorny 1976). These data show that we are constrained in our mental processes of manipulating things similarly to how we are constrained in our physical ability to manipulate things in the real world. Johnson (1987: 25) concluded from his discussion of the mental rotation data that "we can perform mental operations on image schemata that are analogs of spatial operations". In other words, the empirical data suggest that image schemas have a kinesthetic character as they are not tied to any single perceptual modality.

Does our ability to mentally rotate images truly reflect the operation of image schemata? To answer this question, we must be very clear about the differences between mental imagery as typically studied by cognitive psychologists and the idea of image schemas. Both Johnson and Lakoff note that image schemas are not the same as real images which they refer to as "rich" images. Image schemas are presumably more abstract than ordinary images and consist of dynamic spatial patterns that underlie the spatial relations and movement found in actual concrete images. Mental images are also temporary representations, while images schemas are permanent properties of embodied experience. Finally, image schemas are emergent properties of unreflective bodily experience, while mental images are the result of more effortful cognitive processes. For example, research shows that mental images are generated by assembling the parts of the image one part at a time (see Finke 1989).

Despite these differences, there are interesting similarities between mental images and image schemas that make the study of mental imagery especially relevant to our quest for the cognitive psychological reality of image schemas and their transformations. First, real images are typically not as rich and detailed as Johnson and Lakoff originally implied. Various studies show that mental images are not mental pictures in the sense of providing a veridical copy of what has been perceived (Finke 1989).

Visual images are typically constructed from the underlying concepts a person already knows (Chambers and Reisberg 1992; Intos-Peterson and Roskos-Ewoldsen 1989). Some aspects of mental images reflect the operation of visual and spatial representations. Even congenitally blind individuals perform quite successfully on various mental imagery tasks where they are first presented with the object studied tactically rather than visually (Kerr 1983; Zimler and Keenan 1983). These findings suggest that there is no reason to believe a visual representation is necessary for mental imagery. The representation of mental images is neither entirely visual nor entirely spatial. For example, Farah et al. (1988) note that there may be two anatomically distinct cortical systems for dealing with visual representations (one involved in representing the appearance of objects, the other to represent the location of objects in space). Other neuropsychological evidence shows that a patient with brain damage from an automobile accident suffered from several deficits in visual recognition but performed normally on most spatial mental imagery tasks. Most importantly, other aspects of mental imagery are constrained by people's kinesthetic knowledge which, for example, influences their ability to recognize permissible rotations of the body and different body parts (Parsons 1988, 1989).

In summary, although there are significant differences between mental imagery and image schemas, there is good evidence that both spatial and visual representation exist for mental imagery. This conclusion is quite consistent with the idea that different modes of perceptual/bodily experience give rise to cognitive schemes that have analoglike properties. To the extent, then, that people's mental images reflect the operation of various modalities and kinesthetic properties of the body, the experimental findings on mental imagery support the idea that image schemas play a significant role in certain aspects of perception and cognition.

One relatively new body of research that quite specifically points to the role of image schemas and their transformations in mental functioning comes from studies on representational momentum. Before considering these activities, consider first the bodily experience of momentum. This experience is pervasive in daily life. We experience visual momentum when we see heavy moving things continue to move even when encountering other objects. We experience kinesthetic momentum both when we are the object that the heavy moving thing encounters and when we are the heavy moving thing. We experience auditory momentum both as a correlate of visual and kinesthetic momentum and independently as when thunder builds up to a crescendo. We even experience internal momentum as when certain bodily functions build up such that they cannot be stopped. We abstract out of all of these similar experiences those aspects of form which they have in common or which are similar, which we refer to through language as momentum.

The term representational momentum was coined by Freyd and Finke (1984) to refer to an internalized representation of physical momentum. A variety of experiments have studied different aspects of representational momentum. The typical paradigm used to investigate representational momentum consists of the presentation of a sequence of three static images, referred to as the inducing stimuli, of an object (usually a simple geographic shape or a dot) which appears to be moving linearly or rotating in one direction. A final target position of the image is then presented and participants are asked to determine if this target image's position is the same as the third static image of the object. Figure 1 presents a schematic diagram of the experimental paradigm used to study representational momentum. People's participation in a representational momentum task involves their ability to follow in their imagination the path of a moving object and then focus on the point where it will come to rest (an example of the path-focus to end-point focus image schema transformation).

The classic finding from representational momentum studies is that participants' memory for the final position of an object undergoing implied motion is shifted toward the direction of the motion. The effect was first discovered for rotating objects (Freyd and Finke 1984) and was later extended to linearly moving objects (Finke and Freyd 1985; Hubbard and Bharucha 1988). For example, if participants watch an image of an object which appears to be rotating, and then have to remember the final position of the object, they will typically report that the object's final position was further along in the rotation than it actually

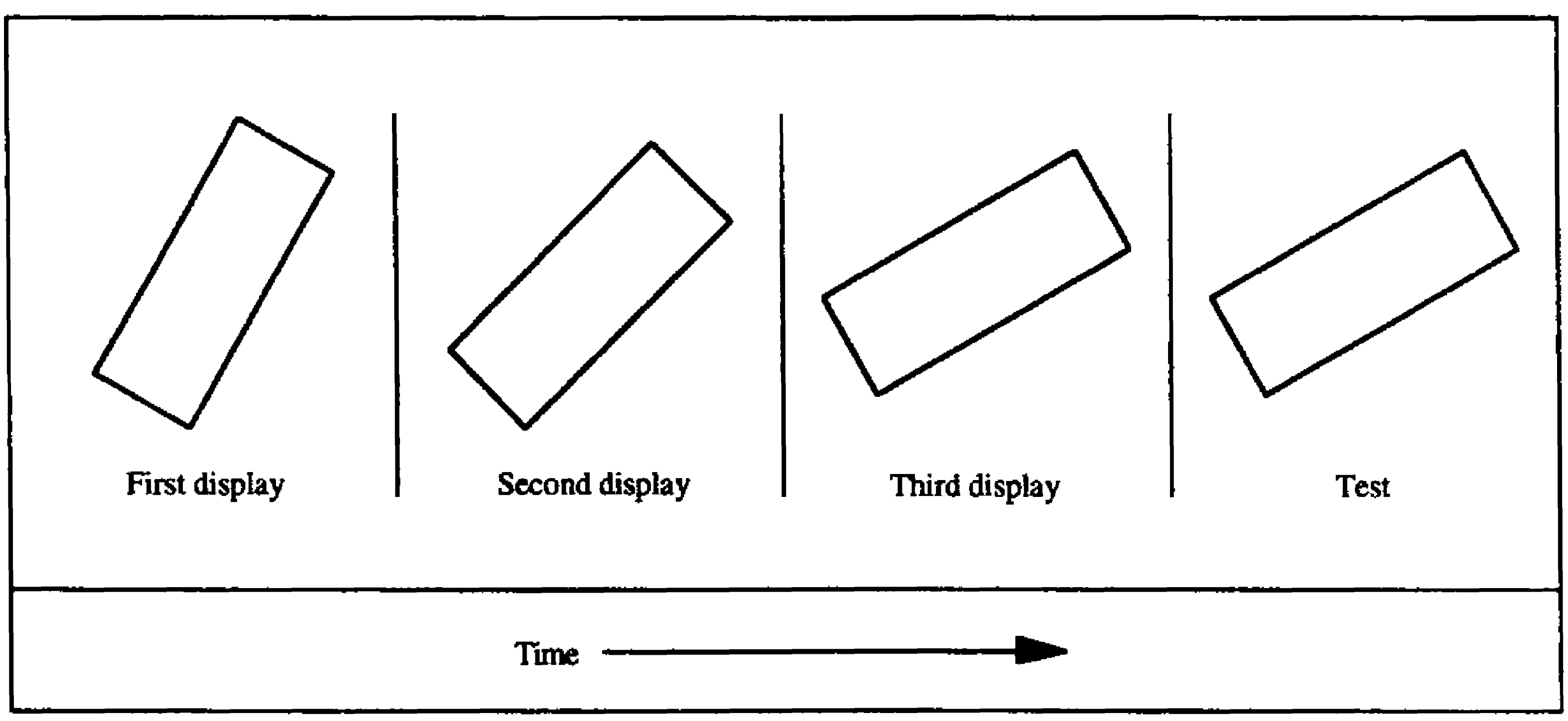

Figure 1. *Schematic diagram of series of events in typical representational momentum experiment*

was. The same sort of effect holds for linearly moving objects. If participants watch an image of an object which appears to be moving along a linear path, and then have to remember this object's final position, they will report that the final position was further along the path than it actually was.

What cognitive psychological principles best explain the phenomenon of representational momentum? The effect is not due to apparent motion because increasing the amount of time up to two seconds between the presentations of the static images still results in representational momentum (Finke and Freyd 1985). Representational momentum presumably "reflects the internalization in the visual system of the principles of physical momentum" (Kelly and Freyd 1987: 369). Indeed, many characteristics of real world physical momentum have been found in representational momentum. For instance, the apparent velocity of the inducing stimuli affects representational momentum (Freyd and Finke 1985; Finke et al. 1986). Participants' memory for the final position of a quickly moving object is displaced further along in its path than if the object is moving slowly. Apparent acceleration of the inducing stimuli also affects representational momentum in that objects which appear to be accelerating will produce a larger memory displacement (Finke et al. 1986). Also, displacements which go beyond what one would expect in real world momentum do not produce representational momentum, (Finke and Freyd 1985). If the target image of the object is in a position such that it corresponds to what would be the "next" position in the sequence of inducing images, or is even further along in the path or rotation than the "next" position, the representational momentum effect goes away.

Furthermore, memory displacement is greater for horizontal versus vertical motion (Hubbard and Bharucha 1988). This may be a result of the predominance of horizontal motion in our environment. Gravity also affects representational momentum (Hubbard and Bharucha 1988). Objects moving downward are displaced more along their direction of motion than objects moving upward. If an object is moving horizontally and then disappears, participants consistently mark its vanishing point to be lower than it actually was. The same result occurs with ascending oblique motion. Interestingly, descending oblique motion usually produces displacement above the actual vanishing point. These results suggest an internalized environmental constraints on momentum. What goes up must come down, what comes down comes down faster than what goes up, things moving linearly usually drop toward the ground, and that which drops at an angle usually ends up moving horizontally along the ground. It appears that representational momentum is something more complicated than a simple representation of what an object's motion is like given it has momentum.

Finally, and importantly, representational momentum effects have not only been found for visual stimuli, but with auditory stimuli as well (Kelly and Freyd 1987; Freyd et al. 1990). Studies with musical pitch have demonstrated that a series of inducing tones either rising or falling in pitch, followed by a target tone either higher or lower in pitch than the third inducing tone produces the same representational momentum effects as with the studies using visual stimuli. This auditory representational momentum appears to not be simply due to a correlation with visual representational momentum, but rather seems only abstractly related to the latter (Kelly and Freyd 1987). Kelly and Freyd introduced the Gestalt property of "good continuation" as a possible explanation for the similarities between visual and auditory representational momentum, but discount the idea saying that it "cannot provide any explanation for the specific quantitative aspects of the phenomenon, such as the fact that the representational distortions increase with the implied velocity of the display. Such effects, however, are predicted by a model of the phenomenon based on physical momentum." (1987: 397).

Many aspects of the data on visual and auditory representational momentum can be explained in terms of image schemas and their transformations. First, the SOURCE—PATH—GOAL schema must underlie critical aspects of representational momentum as a person observes an object move from a starting position along some path toward an imagined goal. The SOURCE—PATH—GOAL schema must be one of the most basic image schemas that arise from our bodily experience and perceptual interactions with the world. Besides the schema of SOURCE—PATH—GOAL there may also be a specific schema for MOMENTUM. When we encounter the inducing stimuli in a representational momentum task, either visual or auditory, a stored representation for momentum is *not* activated. Instead, we use the image schema for MOMENTUM, derived jointly by our minds, bodies and our environment, to expect the next stimuli to be further along in the path, rotation or musical scale. Such an expectation would not occur using only the PATH image schema or FOLLOWING A TRAJECTORY transformation. These may provide the direction that a moving or rotating object is about to traverse, but they cannot account for an expectation concerning the distance that the object will travel given that it has momentum. Yet a MOMENTUM schema accounts for specific, quantitative aspects of visual representational momentum. Thus, our experience tells us that the faster something is moving, the more momentum it will have and thus the more distance it will travel when a stopping force is applied to it. Moreover, the notion of momentum as image schema also explains the cross modal aspects of representational momentum. We abstract away from our experiences of seeing momentum, hearing momentum and feeling momentum those aspects that are shared or which are similar to one another. Thus, we get the same kinds of effects in auditory as in visual representational momentum even though they are not always correlated in the environment (Kelly and Freyd 1987).

The research on visual and auditory representational momentum also illustrates different image schema transformations in that an image schema like momentum can be created by the transformation of other image schemas such as LANDMARK, PATH, BLOCKAGE, REMOVAL OF BLOCKAGE, and GOAL. Image schema transformations like these would function in representational momentum in the following way. First, we invoke the landmark image schema when we immediately attend to an object. As this object moves, we transform the landmark image schema into the path image schema in that our attention is now additionally focused upon the path of the landmark. This is known as the LANDMARK-PATH image schema transformation. We then invoke the BLOCKAGE image schema when the moving object disappears. This image schema is transformed into the REMOVAL OF BLOCKAGE image schema when the target stimuli appears. This transformation is known as the BLOCKAGE-REMOVAL image schema transformation. Finally, to determine the endpoint of the moving object given that it was a landmark moving along a path which encountered blockage which was subsequently removed, we transform the PATH image schema into a MOMENTUM image schema, and then that into an endpoint focus or goal image schema. This gives us information about the likely position of the object given that it had not encountered any blockage.

We use the position provided by image schema transformations to compare to the target stimuli in a representational momentum task. If there is a match between our expected position given by different image schema transformations and the target stimuli, we respond affirmatively. As the representational momentum literature has shown, however, we are frequently mistaken in saying that target positions which are further along the path correctly indicate the position the object would have. This mistake is produced by the PATH-END-POINT FOCUS image schema transformation. This transformation gives us information about where the object should be given that it was moving at a certain speed, in a certain direction, encountered blockage which was then removed. If we were instead relying only upon the information in memory on the actual position of the most recent image of the object, we would not make these errors.

In general, the research on representational momentum shows that different modes of experience, visual and auditory, are structured in very much the same way even though they are not always correlated in the environment. Internalized representations of real world physical momentum are not adequate because of the constraints imposed by our perceptual system. Externalized projections of our perceptions are not adequate because of the real world aspects like gravity. Gestalt principles are compelling in that they capture the flavor of abstracted repeating patterns of form of our bodily experience when interacting with our environment, but they are not adequate by themselves because they do not specify the quantitative details. On the other hand, image schemas and their transformations provide a useful way of explaining different aspects of representational momentum.

Our analysis of the image schemas and the transformations that might be involved in the empirical studies on representational momentum is meant to illustrate something about the importance of bodily experience in human perception and cognition. Many other studies in cognitive psychology show that dynamic events, not single, isolated occurrences, are the basic units of perception. In many cases, people find it easier to make sense of temporal events than they do nontemporal ones, and moving objects over those that are stationary (Gibson 1979; Michaels and Carello 1981). An elegant demonstration of these patterns is found in research conducted by Johansson (1973). In one experiment, lights were placed at the major joints of a person dressed in black and photographed in the dark. Viewing the lights as stationary, observers reported seeing only random arrangements of dots. However, if the person to whom the lights were attached moved by walking, hopping, doing sit-ups, or any other familiar activity, observers will immediately and unmistakenly see a person engaged in that activity. If the lights stop moving, they return to what appears to be a random assemblage. Other evidence indicates that observers detect the sex and even the identity of a person walking to whom lights are attached (Koslowsky and Cutting 1977).

Johansson concluded that the perception of the gestalt pattern of an event progressing in time is basic in ordinary life. He proposed that the perception of a unique structure for continuously transforming point-lights was accomplished by the visual system according to some perceptual vector analysis. A similar conclusion has been offered for how people perceive the movements of the hands and arms through space in American Sign Language (Poizner et al. 1986). But the perception of dynamic events might also reflect the primacy of image schema transformations in human cognition. For example, the ability of observers to recognize that a set of moving lights form a person reflects the involvement of the

MULTIPLEX-TO-MASS image schema transformation where an undifferentiated group of objects begins to take on a coherent, meaningful appearance once movement is detected. The perception of dynamic events over static ones also highlights the importance of the analog component of image schemas.

Beyond our image schematic ability to perceive meaningful configurations from the movement of random dots, people exhibit a capacity for noting meaningful resemblances between different sensory experiences. What enables people, for example, to recognize a resemblance between the faint twinkle of a dim star and a muted tone? When cross-modal similarities appear in language they typically take the form of similes and metaphors. The cross-sensory or synesthetic experience provides one of the simplest kinds of metaphoric language in which one mode of sensory or perceptual experience gets mapped onto another. Phrases such as *loud sunlight, bright thunder, murmur of sunlight*, and *sunlight roar* illustrate just some of the many thousands of examples of synesthesia. Although early studies suggested that synesthetic perception may be relatively rare in adults, studies in recent years suggest that synesthetic perception may rest on a universal understanding of cross-modal equivalence (Marks 1978). Synesthetic matches are not random. People do not arbitrarily combine colors, forms, and sounds. But people do make systematic connections between dimensions of specific modalities, for example, soft and low-pitched sounds are associated with dim or dark colors and as sounds get louder or higher in pitch, the çolors gets brighter (Marks 1978, 1982).

Our ability to appreciate resemblances between relatively abstract properties of visual and auditory experiences may illustrate the emergence of various image schematic structures. We may, for instance, recognize that the image schematic structure for color might have a fixed correspondence with the image schematic structure for sounds. Marks et al. (1987) argue for the existence of abstract supradimensions of experience that make certain combinations of ideas more likely, more natural, than others (e.g., *loud* and *bright* go well together in a way that *loud* and *dark* do not). But we can better argue that constraints on permissible perceptual relations are provided by the invariance principle (Lakoff 1990), which holds that the mappings of source-to-target domain information in metaphors preserve the structural characteristics or cognitive topology of the source domains. Under this view, in synesthesia, people recognize invariant correspondences between the image schematic structure for auditory sounds and visual images and this constrains what combinations of synesthesia are most meaningful.

Image schemas and developmental research

Developmental psychologists have long debated the role of early sensorimotor behavior in cognitive development. Since Piaget's (1952, 1954) writings on how sensorimotor development underlies different aspects of cognitive growth, developmental psychologists have considered ways of linking patterns that emerge from young children's bodily and perceptual experience with later intellectual development. Although Piaget concluded that young infants understood little of the physical events that take place around them, more recent research conducted with sensitive methods suggests that young infants are capable of sophisticated physical reasoning (Baillargeon 1993; Spelke et al. 1992). In recent years, developmental psychologists have even argued that image schemas form the basis for certain concepts that appear to underlie physical reasoning in early childhood (Mandler 1992).

First consider the concept of animacy. People are able to judge motion to be animate on the basis of perceptual characteristics of which they are not aware. There are two broad types of onset of motion, self-instigated motion and caused motion. From early age, infants are sensitive to the difference between something starting to move on its own and something being pushed or otherwise made to move (Leslie 1988). Self-motion is the start of an independent trajectory where no other object or trajectory is involved. By itself an object starting to move without another visible trajector acting on it is not a guarantee of animacy (e.g., a wind-up toy).

Several kinds of simple perceptual analyses give conceptual meaning to a category of moving things. Mandler (1992) claimed that infants use image schemas as they generalize across the particulars of perception to a representation that encompasses some abstract characteristics the experiences have in common. For instance, adults think of biological motion as having certain rhythmic but unpredictable characteristics, whereas mechanical motion is thought of as undeviating unless it is deflected in some way. Given infants' concentrated attention on moving objects, some analysis of the animate trajectories must take place along with the analysis of the beginning of their paths. An example would be noticing that dogs bob up and down as well as follow irregular paths when they move. One study with 1- to 2-year-olds examined how children played with little models of a variety of animals and vehicles (Mandler et al. 1991). The children often responded to the animals by making them hop along the table, but they made the vehicles scoot in a straight line. Thus, very young children appear to understand differences in the movement of animate and inanimate objects.

Various image schemas may underlie young children's understanding of animacy. The contingency of animate movement not only involves such factors as one animate object following another, as described by the image schema LINKED PATHS, but also involves avoiding barriers and making sudden shifts in acceleration. Adults are sensitive to all of these aspects of animate movement (Stewart 1984), but it is not yet known whether infants are responsive to such movement, even though they appear to be perceptually salient. Nor has anyone considered how factors such as barrier avoidance might be represented in image schema form (Mandler 1992). Johnson (1987) described several FORCE schemas, such as BLOCKAGE and DIVERSION, that may be useful in describing barrier avoidance, but these schemas need to be further differentiated to account for animate and inanimate trajectories. One might represent animate and inanimate differences in response to blockage as a trajectory that shifts direction before contacting a barrier versus one that runs into a barrier and then either stops or bounces off from it (Mandler 1992).

Causality and inanimacy are two other concepts important to early conceptual development. The difference between self-motion and caused motion is that in the latter case the beginning of path involves another trajector. A hand picks up an object, whose trajectory then begins, or a ball rolls into another, starting the second one on its course. Leslie (1982, 1988) speculated that a concept of causality in infancy is derived from this kind of perception. His studies, which employed sophisticated dishabituation techniques, showed that infants as young as 4 months distinguished between the causal movement involved in one ball launching another and very similar events in which there is a small spatial or temporal gap between the two movements. In launching, the end-of-path of the first trajectory is the beginning-of-path trajector. In the noncausal case there is no connection between the end of one trajectory and the beginning of the next. Other research also shows that 10-month-old infants can differentiate between causal and non-causal events (Cohen and Oakes 1993), and that 10- to 12-month-olds can make sophisticated calibration judgments about collision events (Kotovesky and Baillargeon 1994).

These different findings on young children's spatial analyses suggest that physical causality might be represented before psychological causality, contrary to what is usually assumed in development (Piaget 1954). The specialization of causal understanding is usually said to begin only after infants experience many occasions of drawing objects to themselves or pushing them away. However, Leslie's (1982, 1988) data suggest that the ontogenetic ordering may be the other way around. The experience of intention or violation may not be required to form an initial conception of causality.

Consider now the child's acquisition of the concepts of containment and support. Containment is quite relevant to preverbal thinking and is an early part of conceptual development. Some concept of containment seems to be responsible for the better performance 9-month-old infants show on object-hiding tasks when the occluder consists of an upright container, rather than an inverted container or a screen (Freeman et al. 1980; Lloyd et al. 1981). These infants already appear to have a concept of containers as places where things disappear and reappear.

Image schemas may explain some of these data. For example, the CONTAINMENT schema has three structural elements (interior, boundary, and exterior) that primarily arise from two sources: (1) perceptual analysis of the differentiation of figure from ground, that is, seeing objects as bounded and having an inside that is separate from the outside (Spelke 1988); (2) perceptual analysis of objects going into and out containers. The list of containment relations that babies experience is long. Babies eat and drink, spit things out, watch their bodies being clothed and unclothed, are taken in and out of rooms, and so on.

Although Johnson (1987) emphasized bodily experience as the basis of the understanding of containment, it is not obvious that bodily experience per se is required for perceptual analysis to take place (Mandler 1992). Infants have many opportunities to analyze simple, easily visible containers such as bottles, cups, and dishes, and the acts of containment that make things disappear into and reappear out of them. Indeed, it might be easier to analyze the sight of milk going in and out of a cup than milk going into or out of one's mouth. Nevertheless, which ever way the analysis of containment gets started, one would expect the notion of food as something that is taken into the mouth to be an early conceptualization.

Another aspect that seems to be involved in an early concept of a container is that of support. True containers not only envelop things but support them as well. Infants as young as 3 months are surprised when support relations between objects are violated (Needham and Baillargeon 1991). Five-and-a-half-month-old infants are surprised when containers without bottoms appear to hold things (Kolstad 1991). Similarly, 9-month-old infants could judge whether a block could be supported by a box open at the top *only* when they were able to compare the widths of the block and the box in a single glance as the one was lowered into the other (Sitskoon and Smitsmon 1991). Finally, Baillargeon (1993) demonstrated that 12.5-month-old infants could determine whether a cloth cover with a small protuberance could hide a small tiger toy only when there were able to directly compare the size of the protuberance to that of the toy. These findings suggest that the notions of containments and support may be closely related from an early age. A primitive image schema of SUPPORT might require only a representation of contact between two objects in the vertical dimension (Mandler 1992).

An infant's understanding of opening and closing is also related to the development of containment. Piaget (1952) documented in detail the actions of 9- to 12-month-old infants performed while they were learning to imitate acts that they could not see themselves perform, such as blinking. Before infants accomplished the correct action, they sometimes opened and closed their mouths, opened and closed their hands, or covered and uncovered their eyes with a pillow. Piaget's observations testify to the perceptual analysis in which the infants were engaging and their analogical understanding of the structure of the behavior they were trying to reproduce. Such understanding seems a clear case of an image schema of the spatial movement involved when anything opens or closes, regardless of the particulars of the thing itself.

Finally, another source of evidence for the psychological reality of image schemas and their transformations comes from the developmental literature on object permanence. Object permanence refers to the belief that physical objects exist even when they are not in the presence of the sensory modalities. Piaget (1954) proposed that infants initially do not share adults' beliefs about occlusion events, but adopt the belief slowly over the first few years of life. One could argue that development of the notion of object permanence can be thought of as the development of several different image schemas, and the workings of transformations between them. Several studies have been conducted whose results are amenable to an image schema account. For example, Baillargeon (1987) has shown that 3.5 to 5.5-month old infants have no difficulty representing the existence of one, two, or even three hidden objects. Infants also appear to represent many of the properties of objects, such as their height, length, and trajectory (Baillargeon and DeVos 1991). Other studies show that infants know that hidden objects, like visible ones, cannot move through space occupied by other objects and an object cannot appear at two places in space without being transported from one point to the other (Baillargeon 1993). 3-month-old infants also appear to have developed knowledge of the physical aspects of people (Legerstee, in press).

These results on object permanence can be thought of as indicating the presence of various image schemas and transformations between them. We propose, following Mandler (1992), that the transformations LANDMARK, to BLOCKAGE, to REMOVAL OF BLOCKAGE, and finally back to LANDMARK underlie the demonstration of object permanence in the 4.5-month olds. The reason the 3.5-month olds do not exhibit object permanence is that they either have not developed one or more of these image schemas or are not yet capable of transforming them. The specific explanation requires more specific tests to determine which is true, but we suspect it has to do with blockage and removal of blockage. This follows from the fact that 3.5-month old infants can already focus on individual objects and thus appear to have developed the image schema for LANDMARK.

Our analysis of the role of image schemas in infants' reactions to physical events differs from many developmental psychologists' views on the origins of knowledge. Various scholars express doubt about the idea that infants' knowledge of physical events are derived as they learn about regularities in their perceptual environment (Spelke et al. 1993). Many psychologists argue that early development for perception, action, and reasoning is modular (Karmiloff-Smith 1992). But we wish to suggest that image schemas and their transformation have some functional role in infants' sensorimotor and cognitive systems.

We earlier discussed some of the research from cognitive psychology on cross-modal matching. There exists a similar line of studies in developmental psychology showing that young children find abstract similarities between different sensory experiences. Research in support of this conclusion has looked at how young children understand various multimodal movements. Detection of intermodal relations is not just a case of association of two experiences that happen to occur simultaneously. For example, 3-month-old infants were familiarized with different visible and audible filmed events (Bahrick 1988). One film depicted a hand shaking a clear plastic bottle containing one very large marble. The other film depicted a hand shaking a similar bottle containing a number of very small marbles. Four conditions varied in their pairings of film and sound tracks as to whether the appropriate track (one or many marbles) was paired with a film or whether a track was synchronomous with the film or not. Only one group of infants was acquainted with films paired with the appropriate, synchronized sound tracks. After familiarization, an internal preference test was given to each group of infants with two films presented side-by-side while a single central track played. The data showed that learning did occur with greater familiarization, resulting in a preference for matching the film specified by its appropriate sound track. But, most importantly, learning was confined to just one group of infants, namely, those most familiar with the appropriate synchronized pairing of sight and sound. Equal opportunity to associate with an inappropriate sound track did not lead to a preference for that combination of the preference test. These findings show that very young children exhibit an ability to acquire abstract relations between events in different modalities.

A different line of research on how children find abstract similarities between different sensory experience comes from work on synesthesia. In one early study, infants were challenged to construct a similarity relationship between two events that shared no physical features or history of co-occurrence (e.g., a pulsing tone and paired slides of a dotted line and a solid line). Nine- to 12-month-old infants looked longer at the dotted line than the solid line in the presence of a pulsing tone suggesting that a metaphorical match was construed (Wagner et al. 1981). Similarly, they looked more at an arrow pointing upward when listening to an ascending tone and to a downward arrow when listening to a descending tone. The infants were thus able to recognize an abstract dimension that underlies two physically and temporally dissimilar events (e.g., discontinuity in the pulsing tone and discontinuity in the dotted line). Another study demonstrated that four-year-olds already perceive and conceive of similarities between pitch and brightness (e.g., low pitch equals dim; high pitch equals bright) and between loudness and brightness (e.g., soft equals dim; loud equals bright). These findings are especially important because they parallel the idea that adults project image schemas from one domain onto another, for example, conceptualizing quantity in terms of verticality (e.g., MORE IS UP and LESS IS DOWN.

Finally, more recent research examined whether infants can construe an abstract unity between a facial expression of emotion (e.g., joy) and an auditory event (e.g., an ascending tone), events that also share no physical features or history of co-occurrence (Phillips et al. 1990). The 7-month-old infants in this study did not categorize different facial expressions of joy and anger. But the infants did look significantly longer at joy, surprise, and sadness when these facial expressions were matched with ascending, pulsing, and descending and continuous tones, respectively. Because the auditory and visual events in this experimental task were substantially different, infants had to act upon the events within a short period of time to bring meaning (i.e., determine equivalences) to the disparity. Thus, infants had to determine the equivalence between both of a pair of facial expressions in concert with the auditory event. This is a striking demonstration of how infants metaphorically match disparate events to construe some meaning in facial expressions of emotion.

The various pieces of empirical evidence on young children's ability to find abstract relations between different sensory events fit in nicely with the claims about image schemas. For us to have meaningful, connected experiences, there must be regular patterns to our actions, perceptions, and conceptions. Image schemas reflect these recurring patterns and emerge through our bodily movements through space, our manipulation of objects, and our perception of the world in which we live.

General discussion

Our aim has been to explore different connections between ideas from cognitive linguistics on image schemas and their transformations and experimental data from psycholinguistics, cognitive psychology, and developmental psychology. The evidence we have reviewed provides only a small part of the experimental data that might be related to how image schemas and their transformations mediate and constitute different aspects of cognitive functioning. To be sure, many of the scholars whose studies we have cited would not immediately agree with our interpretation of their work in terms of image schemas and their transformations. Our discussion suggests that some empirical work, unbeknownst to the researchers who conducted these studies, might actually provide evidence for the cognitive psychological reality of image schemas and their transformations. Although image schemas do not underlie all aspects of meaning and cognition, they are a crucial, undervalued dimension of meaning that has not been sufficiently explored by psychologists.

The fact that one can talk about different kinds of image schemas and different ways in which these can be transformed certainly suggests that image schemas are definable mental representations. But how are image schemas represented given their cross-modal character? Where might image schemas be represented in the brain given that they arise from recurring bodily experiences that cut across vision, audition, kinesthetic movement and so on (i.e., are the SOURCE-PATH-GOAL or MOMENTUM schemas encoded in the visual cortex or some other part of the brain)? The abstract, yet still definable, character of image schemas does not provide easy answers to these questions. At this point, we can only suggest that linguists and psychologists be cautious in making concrete claims about how and where image schemas might be mentally represented. It is even possible that image schemas are not specific properties of the mind but reflect experiential gestalts that *never* get encoded as explicit mental representations. A different possibility is that image schemas might be characterized as emergent properties of our ordinary conceptual systems and therefore are not explicitly represented in any specific part of the mind. Connectionist or neural network systems provide the necessary architecture to model image schemas as emergent properties of human cognition. We raise these ideas to suggest just some of the possibilities of how image schemas might or might not be mentally represented.

There are several ways that looking at experimental work in different areas of psychology might enhance research in both psychology and cognitive linguistics on image schemas and their transformations. First, cognitive linguists should look closer at experimental evidence on nonlinguistic experience to see how different aspects of perception and cognition systematically relate to linguistic structure and behavior. For example, our discussion of representational momentum in mental imagery tasks suggest that certain image schematic properties might be related to various linguistic expressions. Consider the following utterances:

I was bowled over by that idea.
We have too much momentum to withdraw from the election race.
I got carried away by what I was doing.
We better quit arguing before it picks up too much momentum and we can't stop.
Once he gets rolling, you'll never be able to stop him talking.

These utterances reflect how the image schema for MOMENTUM allows discussion of very abstract domains of cognition, such as political support, control, arguments, and talking in terms of physical objects moving with momentum. We may be able to predict important aspects of the inferences people draw when understanding these sentences given what is known about representational momentum from cognitive psychological research.

One of the findings from representational momentum research is that people behave as if an apparently moving object continues to move even after encountering an obstacle. Essentially, the moving object appears to carry the obstacle along with it rather than deflecting off it or stopping. When understanding the sentence *I was bowled over by that idea*, people should infer that the idea was important and that the speaker was convinced by the idea. This follows from one of the characteristics of moving objects—the bigger objects are, the more momentum they have when moving. Accordingly, a big object encountering an obstacle should result in that obstacle being carried along with the big object. Applying the conceptual metaphor IDEAS ARE OBJECTS, one should infer when reading or hearing *I was bowled over by that idea* that the person encountering an important (big) idea would be convinced (carried along) by that idea.

Another result from the research on representational momentum is that objects moving with momentum are perceived as being unable to stop immediately. Even if a force is applied to stop the object, it will continue along for some distance before coming to rest. One might infer from this situation that if reaching a particular destination is desired, then the more momentum an object has the better are the chances for the object to reach the destination. We can apply this knowledge, along with the conceptual metaphor ACCOMPLISHMENTS ARE MOVEMENTS, to the sentence *We have too much momentum to withdraw from the election race* to infer that the candidates in the election race have a good chance (much momentum) to win the election, and therefore shouldn't attempt to withdraw (stop).

A related finding from representational momentum research is that an object with unchecked momentum will move a long distance, perhaps even overshooting some desired destination. This situation informs the inferences made on the sentence *I got carried away by what I was doing.* Specifically, a person doing something without monitoring the time involved or the resources devoted to doing it (an object moving with unchecked momentum) might result in devoting too much time or resources to the task (overshoot the desired destination).

A different aspect of the representational momentum research concerns the apparent speed and acceleration of the moving object. This factor affects the perceived amount of momentum that an object will have. Applying this finding to the sentence *Once he gets rolling, you'll never get him to stop talking* leads to the inference that interrupting (stopping) the person early in the conversation (when speed is low) will be easier than interrupting him later (when speed is high). This result also applies to the sentence *You had better stop the argument now before it picks up too much momentum and we can't stop it.* The inference here might be that arguments start off fairly innocuously (with low speed) but as they progress, things may be said which are unretractible (high speed). For both sentences, we understand that the talking or argument should be stopped as early as possible.

These analyses illustrate how findings from cognitive psychology can be applied to make predictions about people's understanding of linguistic expressions. Cognitive linguists would do well to consider in more detail, following the cognitive commitment, how experimental data relates to the analysis of linguistic structure and behavior. On the other hand, psychologists should consider how many of their experimental findings reflect human embodied experience. Many aspects of language, perception, and cognition may be, at least partly, motivated by image schemas that arise from recurring bodily experiences and our perceptual interactions with the world. Even though many psychologists hypothesize that much of our knowledge is innate and organized as incapsulated modules, significant aspects of how we learn, perceive, think, and use language are intimately intertwined with our ordinary bodily experience. One of our goals in writing this article is to urge psychologists to seek greater connections between their work in perception and cognition and people's ordinary bodily experience.

One significant challenge for both psychologists and cognitive linguists is to find better ways of empirically testing the role of image schemas in perception, cognition, and language. The main argument we have presented is that various empirical data are consistent with the cognitive reality of image schemas and their transformation. Yet we must find ways of *falsifying* the theory of image schemas. It is not enough to show that there are data consistent with image schemas, we must also make specific experimental predictions about human behavior based on our theoretical understanding of image schemas and their transformations. If we cannot make such experimental prediction, then the theory of image schemas will not be potentially falsifiable and will not be recognized by psychologists as having any significant cognitive reality. The psycholinguistic research on *stand* demonstrates that it is possible to examine the psychological reality of image schemas in a falsification framework. We urge both psychologists and cognitive linguists to consider ways of doing similar kinds of experimental research.

Perhaps the greatest contribution of the work described in this article is that it provides additional information on what is especially cognitive about cognitive linguistics (Gibbs, in press). The embodied nature of thought and language can be illustrated not only from analyses of linguistic structure and behavior, but by experimentally examining many of the ways we perceive, learn, and imagine. Experimental studies are especially useful for understanding the important details of unconscious mental processing that cannot be obtained through introspective analysis of our phenomenological and linguistic experience.

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