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Publication Date

2005

Peer reviewed

On the neural basis of image schemas

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1. Introduction

The idea of image schemas emerged from the empirical research on spatial relations terms by Talmy (1972, 1975, 1978, 1983) and Langacker (1976, 1986) in the mid-1970's. They found, independently, that (1) even closely related languages vary widely in the meanings of their spatial relations terms, and that (2) despite this variation, the cross-linguistic differences could be analyzed in terms of combinations of universal schemas -- paths, bounded regions, contact, forces of various kinds, and so on -- together with metaphorical versions of these. Research since then has confirmed and extended their findings, with analyses done of languages around the world.

   The methodology behind these discoveries is commonplace within linguistics. (1) A cross-linguistic search within some natural domain (e.g., spatial relations) is conducted, uncovering diverse and complex systems. (2) A hypothesis is made that the complexity and diversity can be explained in terms of combinations of simple universal primitives. (3) Language-by-language analysis is performed, showing that the same universal primitives combine differently in different languages to yield the observed complexity and diversity.

   Not all linguists work with this explicit methodology. The Nijmegen group, for instance, starts with the same first step of performing a cross-linguistic search in a particular domain. In the domain of spatial relations, for example, the group uses a methodology based on line drawings (see Bowerman 1996; Bowerman and Choi 2001; Levinson et al 2003). Each drawing represents a spatial relation between two objects. The native consultant is to supply the term most appropriate for describing that relation. They find the first result that Talmy and Langacker found: there is a lot of diversity across languages regarding which words name which collection of pictures.

Assuming that universal primitives would be relatively unitary concepts associated with individual words, they consequently argue against the presence of universal primitive and innate concepts. It is important to note, however, that these conclusions are based on a different notion of "universal primitive" than the one used by Talmy and Langacker, who assume that words may express concepts which are themselves complex combinations of primitives. Different assumptions about the nature of universal primitives may thus lead to different choices of methodology and to different conclusions.

Since we take the Talmy-Langacker analyses as deep and insightful, and since we are interested in maximizing explanations from neuroscience, our results are, not surprisingly, very different from those of the Nijmegen group.

By the early 1980's, image schema research had led to a deep question: Where do the universal primitive image schemas come from? Since then, two answers have been proposed: (1) Johnson (1987) saw them as arising from recurrent everyday bodily experiences, such as the early childhood experience of putting things into containers and taking them out again. (2) Regier (1995, 1996) argued that the human brain is structured naturally so as to compute the primitive universal image schemas, and to combine them. These are, of course, not mutually exclusive. Regier's hypothesis explains the *types* of experiences that Johnson observes. That is where things stand today. To get a better idea of the details, let us begin with Johnson's ideas.

1.1.   Motion Experience

Consider motion-related experiences. From the time you first learn to crawl, moving yourself around in the world is a significant part of your daily routine. On a typical morning you might get out of bed, leave the bedroom, and walk to the kitchen to get something to eat. Going outside, you may then jog around the block, run away from an angry dog, bicycle to work, or drive to the store. What types of image-schematic structures are associated with such basic experiences as these?   To answer this, we first have to have some idea of what an image schema is. Johnson (1987), using an experiential approach, proposed the following defining elements: (1) recurrence across many different experiences; (2) a relatively small number of parts or components; and (3) an internal structure that supports

inferences. Considering the motion experiences just mentioned, we can see that while they clearly differ in some respects (e.g. what time of day it is, how far we move, whether food is involved in the experience), all of them have at least one very schematic commonality: they involve a change in the mover's location. These locational changes have the structure of the very basic SOURCE-PATH-GOAL image schema (Johnson 1987; Lakoff 1987): we are one place when we start to move (a Source location); over time we change location (a series of Path locations); and when we stop moving, we are usually somewhere different than where we started (a Goal location). This very basic schema has few parts (Mover, Source, Path, Goal), applies over a very wide range of motion situations, and supports inferences (e.g. if you are at the goal location you have already been at the source and path locations).   Thus, we see that recurrent, everyday motion experiences display at least one kind of image-schematic structure.

1.2.   Moving Beyond Experience

To gain a fuller understanding of image schemas, though, we need more than an experience-based analysis. Our next step will be to examine the image schemas associated with descriptions of motion events, using the linguistic methodology described in the introduction. We will start with an analysis of some English sentence examples, and will then look at work done on cross-linguistic variation and universality.   An examination of motion descriptions indicates that, in addition to containing a variety of spatial image schemas, they contain other kinds of image schemas as well. Linguistic analysis thus helps us identify the existence of primitive image schemas. Moreover, linguistic analysis can lead to a better understanding of how different languages may use and combine these primitive image schemas.

However, linguistic analysis does not, by itself, explain the origins of image schemas. And, even though image schemas may be associated with recurrent regularities in experience, an experiential analysis by itself does not explain how languages may make use of these schemas, nor does it explain why we perceive the particular schematic structures we do. In order to provide more complete explanations, we believe it is necessary to consider the role of the human brain. In the second half of the paper we will therefore pursue Regier's line of argument that the brain computes image schemas. First, we review some of the work that supports the link

between image schemas and neural structure.   Then, we will once again focus on motion experiences and descriptions, exploring a hypothesis about the relation between image schemas and particular neural structures. Through such an analysis, we will show how the study of the brain not only can lead to a fuller understanding of image schemas, but also can provide insight into the relations between image schemas, experience, language, and the brain.

2.   Image-schematic Structure in Language

2.1.   Image Schemas, Experience, and Language

Image schemas structure our experience independently of language. For example, we experience many things as containers — boxes, cups, baskets, our mouths, rooms, and so on. Prior to learning language, children go through a stage of exploration in which they repeatedly put things in and take them out of many different kinds of objects, thus treating these objects as containers. Starting at an even earlier age, they observe actions such as these being performed by others.   As Mandler (*this volume*) describes, infants show some understanding of containment well before their first birthday.

   Image schemas play a vital role in fitting language to experience. Image schemas define classes of experiences that are characterized by the same word (e.g., *in* or *out* or *up*). This fact raises two questions: How is it possible for different experiences to have the same image-schematic structure? And how are image schemas expressed in language? We will start with the second question, and get to the first later in this essay. What is of note is that the way image schemas are expressed in language is a central feature of linguistic structure. Image schemas may be expressed through the use of many different linguistic forms, including prepositions, postpositions, verbs, cases, body-part metaphors, or morphemes (e.g., in Cora, as described by Casad and Langacker (1975)). Which forms a given language uses is a typological feature of that language.

2.2.   English examples

When we describe a person's motion, what sorts of image-schematic structure do we express? Consider the following two sentences: 1) *He walked <u>to</u> the kitchen;* and 2) *He walked <u>into</u> the kitchen.* Both of these sentences indicate that a mover (*he*) is changing location with respect to a "landmark" (*the kitchen*). But these locational changes are only schematically specified; all we can really infer from these sentences is that initially the mover was not at the kitchen, then he moved, and after moving the mover was at or in the kitchen. Both of these motion descriptions thus seem to express SOURCE-PATH-GOAL schematic structure.

The second sentence expresses additional schematic structure, which serves to further specify the spatial relation between the mover and the landmark. The first sentence only indicates, roughly, that at the end of motion the mover is somehow co-located with the kitchen. This may mean that the mover is inside the kitchen, but could also mean that he is directly outside it, or that he is standing in the doorway. The second sentence, however, using the preposition *into,* indicates that the goal location is actually <u>inside</u> the kitchen and the source location is somewhere outside the kitchen. In this case, schematic structural elements of the landmark are used to indicate the mover's location; that is, the kitchen is understood as a container. The kitchen walls effectively divide space into an interior (the space enclosed by the walls) and an exterior (the space "surrounding" the kitchen). In addition, these walls have some opening, such as a doorway, which allows the mover to go from the exterior to the interior of the kitchen. Thus, the following schematic elements seem relevant:

- Boundary (in this case, the walls, which define the shape of the room)

- Interior (a space enclosed by the Boundary)

- Exterior (the surrounding area -- space not enclosed by the Boundary)

- Portal (an opening in the Boundary that allows motion between the Interior and Exterior)

Taken together, these schematic elements define what is often referred to as the CONTAINER schema. These same structural elements are unconsciously and automatically used to conceptualize a variety of objects of various sizes: cups, boxes, bags, rooms, tents, buildings, valleys, etc. Not surprisingly, then, in addition to descriptions of people moving around in

the world, this schema may also be used in descriptions of other types of experiences, such as putting food in your mouth or apples into a basket.

Some motion descriptions specify location by making use of these same schematic structural elements of a landmark, but specify a different temporal order of spatial relations. For example, in *Harry sauntered out of the room,* Harry is initially inside the room then moves to the exterior, the opposite of the sequence specified by *Harry sauntered into the room.* These changes in location can be analyzed in terms of SOURCE-PATH-GOAL schematic structure: *out of* indicates that the exterior is the Goal location, and *into* indicates that the interior is the Goal. Each of these sentences thus expresses both CONTAINER and SOURCE-PATH-GOAL schematic structure, but combines these schemas in different ways.

These facts are so obvious that the theoretical implications of them could easily be missed: the same image-schematic elements can appear in reversed order in a language with a minimal shift in linguistic form (*in* → *out*) indicating the reversal. That is, *in* and *out* are not utterly different. They are inverses. But this can be seen only via an image-schematic analysis of language.

Similarly, the experiences of moving in and moving out are also understood as inverses — but only because the experiences themselves are structured by image schemas. Because image-schematic structuring of experience is done automatically and unconsciously, it escapes notice.

Our experience of a room may be structured image-schematically in many ways, though a given sentence may only focus on one of these ways. For example, a room is experienced as a container, but it is also experienced as having different sides. This second experience is focused on in *Harry sauntered across the room.* The use of *across* indicates that the mover (*Harry*) is moving from one side of a landmark (*the room*) to the opposite side. These sides may be determined based on the geometry of the landmark -- in particular, its axial structure. In this particular example, the relative lengths of the room's walls may serve to define a main axis that effectively divides the interior of the room into two sides. In this example, then, as Harry moves from one side to the other side of the room, he crosses this main axis.1   Sometimes, sides may be considered inherent to a

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1 Commonly, *across* is used with long, thin landmarks. In such cases, the entire landmark may be considered an axis. This axis may serve to the divide the space surrounding the landmark into two areas, each of which might be called a side.

landmark, as in *The shadow moved across his face*, where a face has inherent sides.

Motion descriptions vary not only with respect to which schemas they express, but also with respect to which grammatical forms are used to express this schematic information. In the examples we have examined thus far, the verb (*walk, saunter*) indicated that the mover was moving, the preposition (*to, into, out, across*) gave information about the schematic spatial relation between the mover and a landmark, and the prepositional object (*the kitchen*, *the room*) specified which landmark was being used. However, in other sentences, the schematic spatial relation may be indicated by the verb rather than by a preposition. For example, in *He entered the room*, the verb *enter* not only indicates that the person is moving, but also indicates that he is moving into the room. *He exited/crossed the room* indicates motion out of or across the room. In such sentences, no preposition appears, and the landmark entity is indicated by the direct object of the verb. While both of these ways of encoding locational information use similar schematic structure to specify location, they differ in other important respects, as we will see later in this paper.

By analyzing sentences that describe a person's motion, we have found a variety of schematic structures. The basic temporal sequence of the mover's change in location is expressed using SOURCE-PATH-GOAL schematic structure. Different types of schematic structural elements of the landmark can be used to further specify (albeit schematically) the mover's locations. Furthermore, we have seen that schematic spatial relations information can be encoded in at least two different grammatical forms -- prepositions and verbs.

If all this seems simple and obvious, it is only because we are taking for granted the image-schematic structuring of experience and taking for granted the fact that image schemas exist independently of the linguistic forms used to express them. In a theory without image schemas, none of this would even make sense, much less be obvious.

Thus far, however, we have looked at only one language. If we are to investigate whether image schemas such as those described above are universal primitives, we need to consider a much wider range of languages. Therefore, we next turn our attention to cross-linguistic studies of spatial descriptions.

2.3.   Cross-linguistic Variation and Universality

The image-schematic structuring of experience means that primitive image schemas are *available* to be expressed *somehow* in a given language. But, as Talmy's and Langacker's initial cross-linguistic studies showed, there is significant diversity in the ways languages describe space and location. Consider just a few examples:

- Importance of landmark's shape and/or orientation.

For many spatial relations terms, the shape and orientation of the landmark does not play a role. For example, *above* (and many other English prepositions, such as *in*, *on*, *to*, and *under*) can be applied to landmarks of different shapes and orientations, as in *The bird is above the birdhouse/tree/table*. Compare this with Mixtec, which uses body part terms as a primary means of expressing location. For vertically extended landmarks, locations are described using body part terms of upright bipeds. For instance, an object described in English as being *above* a tree would be considered in Mixtec to be located at the tree's "head". If the landmark were horizontally extended, body part terms for a quadruped on all fours would be used; something *above* a landmark such as a table would be at the landmark's "back" (Brugman 1983). Thus, Mixtec uses two different spatial words to describe scenes that in English would be labeled the same.

- Presence or absence of contact.

Some spatial relations terms distinguish between the presence and absence of contact. For example, English terms *on* and *above* make this distinction for vertical object-landmark relations. In the Mixtec examples discussed above, however, the same spatial term would be used regardless of whether or not the object was in contact with the landmark.

- Tight versus loose fit.

When expressing directed motion, Korean verbs distinguish between relations involving "tight" fit and "loose" fit rather than distinguishing between containment and surface support. (Choi and Bowerman 1991; Bowerman 1996; Mandler *this volume*).

However, despite this cross-linguistic diversity, the number of primitive image schemas used by spatial terms seems to be fairly limited. Talmy (1983, 2000) has conducted an extensive cross-linguistic analysis of the grammatical forms used in the linguistic description of space. Based on his analysis he surmises that there is a limited inventory of basic spatial

distinctions that languages will make in their closed class2 systems. This inventory of basic distinctions includes:

- Focal distinctions within a scene -- figure (focal object) and ground (secondary focus, serves as reference object to locate figure)

- Figure and ground geometries, relative orientations

- Presence/absence of contact of the figure with the ground

- Force-dynamics – reflects non-visual modalities, and is largely independent of other spatial distinctions

Lakoff (1987) has used the term "primitive image schema" for such primitives. Within a Talmy-Langacker style theory, then, there are a limited number of primitive image schemas present in spatial descriptions of different languages, at least in their closed-class forms.

If this inventory is universally available, why do languages exhibit such diversity? Talmy proposed that the spatial relations terms used in language are actually complex concepts composed of primitives selected from this inventory.   Thus, the spatial relation encoded by a given form (say, *into*) may actually evoke a complex of schemas (CONTAINER, SOURCE-PATH-GOAL) rather than being related to only a single primitive schema. In support of this idea, Langacker and Casad (1985), Lindner (1982, 1983), Vandeloise (1984, 1991) and Brugman (1988) have provided detailed image-schematic analyses of spatial terms showing how their meanings may be decomposed into such primitives (though there is some controversy about which decompositions are cognitively correct).   Additionally, as indicated earlier, the spatial relations terms of a given language may not necessarily make use of all of these schematic spatial distinctions. For example, although the tight-loose distinction structures the experience of English as well as Korean speakers, Korean makes use of this distinction but English does not. Thus, while spatial relation terms utilize primitive image schemas, there is by no means a one-to-one correspondence between the spatial relations terms of a given language and the primitives in this presumably universally-available inventory.

Additional cross-linguistic variation in locational descriptions may arise for a somewhat different reason: languages may vary in terms of which

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2 A closed class is one whose membership is fixed and relatively small (Talmy 2000).

frame(s) of spatial reference they use to specify spatial relations. Based on the study of a broad range of languages, Levinson (2003) and others (Talmy 2000) concluded that these languages grammaticalized or lexicalized three different frames of reference.

- One is an intrinsic frame of reference, where spatial coordinates are determined using "inherent" features of the landmark object.

For example, in *He ran into the room*, the spatial relation *into* makes use of the inherent image-schematic structure of the room to specify the mover's location.

- A second type is a relative frame of reference, where the determination of spatial coordinates is made relative to a particular viewpoint.

This frame of reference may also involve the use of a landmark and schematic structure. However, the schematic structure in this case is not inherent to the landmark. So, for example, in *He ran in front of the tree*, "front of " makes use of the front/back elements of a body schema. But, rather than being inherent schematic structural elements of the tree, they are associated with a viewer of the scene (typically the speaker). Thus, while a landmark object is present, the viewer serves as the schematic "anchor" for this frame of reference.

- The third frame of reference that they found is an absolute frame of reference.

As an example, *He ran north* does not include reference to a particular spatial landmark. Instead, location is specified with respect to fixed bearings. In this case the language user has to conceive of the environment itself as having pervasive schematic structure of a kind similar to the pervasive up/down structure supplied by gravity. Languages vary in terms of which of these frames they use. For example, some use both the relative and the absolute frames, while others use one but not the other (Pedersen et al, 1998). So, different elements – landmark, viewer, environment as a whole – may serve to anchor the frame of reference for locational descriptions and spatial relations terms in different languages. Spatial descriptions may thus include specifications of both spatial schematic structure and spatial frame of reference. In this way, they may indicate which element of the spatial environment the evoked schematic structure is linked to.

In sum, we have seen that there is great cross-linguistic diversity in spatial relations terms and their use of schematic structure. Languages differ as to the basic spatial distinctions they make, the combinations of

distinctions they "package" together in their spatial relations terms, and the grammatical class membership of these spatial terms. Use of different frames of reference for spatial descriptions is an additional source of variation. Given this linguistic diversity, we can see that if we were to call each spatial relation term in a language an "image schema", then we could rightly say that languages differ widely in their inventory of spatial image schemas. However, we have also seen that these spatial relations terms can instead be analyzed as complex combinations of more primitive image-schematic structures. Consequently, if we restrict application of the term "image schema" to these primitives, cross-linguistic analysis indicates that there is a limited inventory of image schemas used by the world's languages.

> 2.4.   Other types of schematic structure in language: manner of motion

Thus far in our analysis of motion descriptions, we have concentrated on the image schemas used to convey information about the mover's change in location. However, motion descriptions can include other types of motion-related information. Consider the following sentences: 1) *She sprinted;* 2) *He trudged many miles;* 3) *We strolled arm in arm.* These sentences do not specify anything about where any of these movers are or where they are going. However, the verb in each of these sentences specifies something about the <u>manner</u> in which the mover is moving. *Stroll*, for example, indicates that the mover is walking slowly and leisurely, while *sprint* indicates a fast running motion. In English there are a large number of verbs that can be used to describe different manners of self-generated, animate motion, including *walk, march, stroll, amble, pace, saunter, limp, skip, jog, run,* and *sprint*, to name just a few.

   Are there image schemas associated with these "manner" verbs? While the schemas used in spatial relations descriptions don't seem applicable, an examination of these verbs indicates the presence of other types of schematic structure. Many of these verbs describe variants of a basic walking gait (*walk, march, saunter, amble, pace, tramp*), some describe types of running (*run, jog, sprint, trot*), while others involve jumping of some form (*jump, hop, skip, gambol, leap*). So one schematic element in manner-related information may be the basic gait or general rhythm of muscular activity that the mover is using to bring about his motion. Within

any one of these basic gaits (*walk, run, jump*), different verbs indicate different speeds of motion. For example, *saunter* is a low speed walk, while *striding* is a higher speed walk. Manner of motion verbs may also give a schematic indication of how much effort is required on the part of the mover to actually move. *Trudge,* for instance indicates greater effort than *walk*, while *stroll* implies less effort.   However these verbs don't specify the mover's exact speed of motion or the absolute amount of effort expended.   Speed and effort are only schematically specified, not quantified. Manner verbs may also schematically specify the part(s) of the body used in motion; while most predominantly involve the use of our feet and legs, some may involve the use of hands and arms (*crawling, climbing*).   Taken together, these different types of manner-related information suggest that manner verbs may make use of the following schematic structural elements: Mover, Gait (e.g. *walk, run, jump*), Speed, Effort, and BodyPart. If we consider these elements to be different roles in a single schema, we can say that they collectively constitute what might be called a "Locomotion" schema for self-motion.   This schema meets Johnson's criteria for image schemas, described at the beginning of this paper: in addition to applying across a wide range of situations and containing a limited number of structural elements, this schema supports some types of inference. For instance, we can infer that if a person is sprinting she isn't walking, but is running. Also, if a person is trudging we can infer both that she is moving more slowly than she would be if she were running and that her motion is more effortful than it would be if she were strolling. So, while this LOCOMOTION schema is not one commonly described in the literature on image schemas (but see Mandler 1992; *this volume*)3, it does seem to meet the criteria for being an image schema. Consequently, manner verbs such as these do seem to express image-schematic structure.

So, motion descriptions that convey manner-related information, as well as those which convey locational information, both express image-schematic structure, albeit of different kinds. Some sentences include both kinds of information. For example, manner verbs often appear in sentences

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3 Mandler's Motion schemas distinguish biological from non-biological motion based mostly on the path of motion. For Animate-Motion, the entity's motion does not follow a straight line and may have some rhythmic characteristics. Unlike the LOCOMOTION schema (described more fully later in this paper), the Animate-Motion schema is not explicitly related to the locomotor action performed by the animate entity, and consequently does not include roles for gait or effort.

that also contain locational information, as in *I strolled across the garden* or *I trudged over the hill.* As discussed previously, the locational information in such sentences is schematically specified using a spatial relations preposition (*across, over*); manner verbs themselves do not themselves specify anything about the path of motion. Recall too that verbs can also encode locational information. "Path" verbs such as *enter, exit,* and *cross* supply information about the mover's path of motion, but not about the mover's manner of motion. So, a sentence like *He entered the room* can be used felicitously regardless of whether the mover walked, sprinted, hopped, or even crawled into the room. Manner-related information can be included in such sentences through the addition of adverbs (*slowly, effortlessly*) or phrases (*on foot, at a run*). We see, then, that English verbs can supply either manner or path of motion information, though a given verb does not seem to include both. Sentences may convey path, manner, or both types of information. Because each type of information is associated with different kinds of image-schematic structure, these verbs and sentences will vary as to which kind(s) of image schemas they express.

Looking across languages, there appear to be two predominant lexicalization patterns associated with motion descriptions. One pattern is to encode path information in verbs, and (optionally) encode manner information in other grammatical elements, such as adverbs. The other pattern is to encode manner information in verbs and (optionally) encode path information in other grammatical elements, such as prepositions. Within a given language, there is a tendency for one of these lexicalization patterns to predominate (Slobin 1996, 2003; Talmy 1985, 2000). As we have seen in English, both patterns are present, but manner encoding predominates. Many other languages, such as Russian, Chinese and Ojibwe also predominantly encode manner. In other languages, such as Spanish, Japanese, and Turkish, path encoding in the verb predominates. Languages thus differ in terms of which type of motion information they tend to encode in the verb. Furthermore, since each type of motion information is associated with a distinctly different type of schematic structure, we can also conclude that languages differ in terms of what kind of schematic information they tend to encode in the verb.

What are the possible implications of these encoding differences? Slobin has proposed that lexicalization patterns may affect how we think about motion events. In particular, he suggests that different mental imagery may be associated with each lexicalization pattern. Supporting

evidence for this idea comes from an experiment in which speakers read passages in their native language, either Spanish (where path is encoded in the verb) or English. In neither language did the passage include any manner information, but it did include information about the terrain and the mover's internal state. Speakers of Spanish reported images related to the physical surroundings of a scene, but not imagery related to the manner in which a mover is moving. Speakers of English tended to have mental imagery related to the manner in which the mover is moving. Bilinguals of both languages reported more manner imagery and less imagery related to surroundings when reading in English compared to reading in Spanish. (Slobin 2003). Thus, there seems to be a correlation between the type of information that is typically encoded in the verb of a language (i.e. the type of information the language user typically has to attend to while using that language), and the type of imagery the reader has while reading in that language. Moreover, it may well be that these differences in imagery correspond to the different types of image-schematic structure associated with these two types of information. We will pursue this possibility later in this paper, as well as considering how the different types of imagery may correspond to the activation of different neural structures.

2.5.   Language Section: Summary

As we saw in this section, linguistic analysis provides a methodology to study image schemas. An examination of motion descriptions shows that they commonly include two types of information – path and manner -- and that different types of image schemas are associated with each of these types of information. For the spatial schemas used in path descriptions, we briefly reviewed some significant cross-linguistic work that explored issues of linguistic diversity and primitives. From this we saw that although the spatial relations terms and locational descriptions used by different languages may differ in many respects, they may nonetheless all may make use of the same relatively limited inventory of basic primitive image schemas and frames of reference. From this work we can also see that it is important to clarify what we mean when we use the term "image schema". We need to make a clear distinction between the complex schematic structures of individual spatial relations terms and the primitive, simpler image schemas which are combined to form such complex structures. We also saw that manner-of-movement information seems to have schematic

structure, albeit of a different kind than spatial image schemas. Additionally, languages vary in terms of which type of motion-related information their verbs tend to encode. Because different types of schemas are associated with these two different types of motion information, this variation implies that different types of schematic structure may be associated with the verbal systems of different languages.

However, while cognitive linguistic analysis in the Talmy-Langacker tradition helps us determine what the inventory of primitive image schemas may be, it does not provide us with an answer to the deep question mentioned earlier in this paper: Where do universal primitive image schemas come from? *Why* do the primitives that Talmy and Langacker have found exist? While Johnson's experiential approach goes some way towards addressing this question, we believe that to answer it more fully it is essential to further pursue Regier's arguments, looking at how the structure of the human brain may compute primitive image schemas as well as how it may combine them to form the more complex schematic structures found in different languages. The brain is thus the seat of *explanation* for cognitive linguistic results.

But there is an even deeper reason for looking to Regier-style brain-based characterizations of primitive image schemas. By looking to the brain, we see why there *should* be primitive image schemas, and why they *should* structure experience independently of the language that expresses them. In short, what we know about the brain leads us to choose among linguistic theories. That knowledge leads us to choose Talmy-Langacker style theories with combinations of universally available primitives over Nijmegen-style theories, where each language has spatial relation terms that are not decomposable into primitives, but are just different – and may differ arbitrarily. In short, neuroscience matters for linguistics.

Therefore, we will now shift our attention to the question of what the study of the brain can tell us about image schemas.

3.   Neural structure and image schemas

Regier (1996) expanded on Talmy's previously discussed work on spatial relations. Regier proposed that spatial relations primitives were the consequence of brain structure -- specifically, human perceptual mechanisms. Further, he proposed that spatial relations terms could be learned as different complex combinations of these primitives. He

demonstrated the plausibility of his proposals by creating a computer program that could, from a set of labeled scenes, learn spatial relations words from a wide variety of languages (e.g. English, Mixtec, German, Russian, Japanese). Within this program, perceptual mechanisms were modeled using two classes of visual features: orientation features such as verticality, and topological features such as contact and inclusion. These features form the basis of much of the image-schematic structure expressed in spatial relations words. For example, given the shape of a landmark object, topological maps are used to compute CONTAINER schema roles – *boundary*, *interior*, *exterior* – in part by using a spreading activation procedure. Comparison of trajector and landmark maps determines the trajector's relation to the landmark in terms of these schematic roles. Other features support other schemas. The program uses this model in conjunction with a neurally-inspired connectionist network to learn different spatial relations words. Significantly, this learning process does not simply involve matching a word to a single pre-existing, pre-packaged concept; instead, it requires the combination of evidence from several perceptual structures. Thus, Regier demonstrated that the meaning of a given spatial relations term involves complex combinations of primitive, neurally-plausible image schemas.

Regier's work is significant in two respects. It supports the idea that primitive image schemas are based on specific types of neural structure. In addition it supports Talmy's analysis that cross-linguistic diversity in spatial relations terms may reflect different ways of using an "inventory" of such primitive schemas. However, his model was an oversimplification in many respects. While his model was motivated by brain structure and processing, it was not based on a detailed analysis or modeling of actual neuroanatomy. Additionally, while many properties of image-schematic structure are included in this model, it was not designed to support inferences.

Narayanan (1997) looked at the neural basis of a different kind of schematic structure. He proposed that aspectual structure in language could be modeled as aspectual schemas, that these schemas are neural structures in the premotor cortex of the brain, and that aspectual inferences are arrived at by neural computation over these neural structures. In addition, he showed how metaphorical inference might utilize this same set of structures. The computer program he created demonstrates how neurally-based schematic structure can support inferences.

Importantly, Narayanan's model fits with the theory of neural simulation, which proposes that imagining and talking about an action utilizes some of the same brain structures as are used to actually execute that action (Lakoff & Johnson 1999). This theory is supported by recent neuroscientific research, which has found evidence that neural networks active when performing an action are also active in other circumstances. There are three key findings. (1) Imagining an action or perception activates much of the same neural network as is active when actually performing that action or experiencing that perception. (see Kosslyn et al. 2001 for review). (2) Observation of an action activates much of the same neural substrate as actual execution; certain visuomotor neurons (named mirror neurons) in the motor system discharge both when an individual performs an action and when he observes someone else performing that action (Di Pellegrino et al. 1992; Gallese et al. 1996; Rizzolati et al. 1996; review in Rizzolati & Craighero 2004). (3) Particulary significant are recent studies which indicate that language (verbs and sentences) denoting actions performed by different body parts (mouth, arms, feet) activates some of the same regions as are active when each type of action is actually performed (Hauk et al. 2004; Hauk and Pulvermuller 2004; Tettamanti et al. 2005). In addition to supporting simulation theory, these findings also suggest an avenue of research; in order to discover the brain structures that are used when we talk about a type of event, we should investigate the brain structures that are used when we imagine, observe, or physically experience that event.

During actual experience, many different parts of the brain will typically be active. But which of these areas compute the image schemas we find in language? Lakoff's *Cog theory* proposes some answers to this question. Firstly, Lakoff noted that Narayanan's aspectual schemas are located in "secondary" rather than "primary" motor areas of the brain (see Gallese and Lakoff, *in print*; presented in 2003 at ICLC). Secondly, he noted that Narayanan's aspectual schemas not only structure motor-control experiences, they also compute the semantics of grammatical elements of language. Moreover, he realized that this same set of properties applies to many additional cases, including Regier's spatial image schemas. In all of these cases, there is a structure that seems consistent with that of secondary sensory-motor areas, and this structure applies not only to experience, but to grammatical elements of language as well. Lakoff termed each of these cases a "cog".

What are the differences between primary and secondary brain areas, and why are they significant? Primary sensory-motor areas are concerned with processing information related to a particular modality (visual, auditory, tactile, motor-control), and are fairly directly connected to the receptors or effectors related to that particular modality (eyes, ears, skin, muscles). Secondary sensory-motor areas are connected to primary areas and, of particular importance, some neurons within these secondary areas are sensitive to more than one modality of information. For example, secondary motor areas integrate motor, visual, and somato-sensory modalities for the purpose of performing motor functions. The neural structures found within secondary areas, then, apply not to just one modality of experience, but to multiple modalities.

As with other cogs, then, we would expect image schemas to be computed by neural circuits used in multi-modal sensory-motor operations (Gallese and Lakoff, *in print*). It should not be surprising that these neural circuits are multi-modal since the image schemas they compute are multi-modal as well. As an example, consider the CONTAINER schema. Experientially, containers may be perceived visually, through touch and/or through motor activity (putting objects into and taking them out of containers). In language, CONTAINER schemas can appear in descriptions of many kinds of physical events, experienced through different modalities (*I saw a cat in the box, I felt a coin in my pocket*), as well as being used metaphorically (people in different states of mind, objects in a category). Accordingly, we would not expect the neural circuitry that computes image schemas to be restricted to a particular modality.

We would, however, expect a variety of neural circuits to be involved in the computation of image schemas. Different parts of the brain perform different functions, and make use of different types of information to perform these functions. As a consequence, the neural circuitry of different brain areas will presumably impose different types of structure on experience and compute different image schemas. However, we would not expect these neural circuits to be unrelated to one another. The brain is necessarily highly interconnected; to function in a coordinated fashion, different parts of the brain must be able to "talk to" and "work with" one another. Additionally, there will be some degree of overlap between the information used by different brain areas since, for instance, information originating in a particular primary area may be used by several secondary areas. Thus, while different brain areas may impose different types of

image-schematic structures on experience, brain structure also relates these structures to one another.

Brain structure also affects linguistic structure. In particular, we presume that the neural circuits that compute image-schematic structure also provide the neural substrate for image-schema-related language, such as closed-class spatial relations terms. As we saw earlier in this paper, spatial relations words are not, however, linked one-to-one with individual primitive image schemas. Instead, they are linked to complex schematic structures, which may often exhibit radial category structure (Lindner 1983, Brugman 1981). This is natural, considering the way the brain is structured. The neural circuitry computing a primitive image schema does not operate as a completely independent or isolated module. Instead, it is interconnected with other brain areas, including neural circuits that compute other image schemas. Consequently, it is not surprising that spatial relations words are frequently linked with different complex combinations of related image-schematic structures.

3.1.   Neural basis of schemas used in path and manner of motion descriptions

Where can we go from here? How can we use these findings and theories about the neural basis of image schemas to further explore the relation between image schemas, experience, language and the brain? In this section we will address these questions by exploring a hypothesis about the neural structure supporting path- and manner-related schemas.

Briefly, here is the hypothesis and the reasoning behind it. Based on the theory of neural simulation, we would expect that some of the same neural structures that are active during motion experiences such as walking and running would also be active when we imagine or talk about such experiences. While many areas of the brain are active during actual experience of motion, we would expect only a subset of these areas to serve as neural substrates for language. Furthermore, we would expect this subset of active areas to include the neural circuitry that computes motion-related schemas. And, in accordance with *cog theory*, we would expect such neural circuitry to be found in multi-modal secondary brain areas rather than in more primary sensory-motor areas. Since the experience of path of motion (e.g. moving in a direction, changing location) is different than that of manner (e.g. moving legs quickly), we would expect different

neural substrates for each. Consequently, we would expect the schemas associated with each of these types of experience to be computed by different neural circuits. Based on these expectations, we more specifically propose that: (1) path schemas may be computed by the neural circuitry of multi-modal secondary areas concerned with keeping track of where we are in the world, and (2) manner schemas may be computed by the neural circuitry of multi-modal secondary areas concerned with moving the body.

If this hypothesis is correct, we might further expect to find that processing these different types of motion information is correlated with activity in different regions of the brain. This possibility could be tested by, for example, measuring the brain activation patterns of a person who is listening to or reading different types of motion descriptions.   If different brain areas are active for each type of motion information, this may suggest a neural basis for the differences in imagery reportedly associated with path and manner languages.

Before proceeding with an investigation of the claims put forth in this hypothesis, some caveats are in order. First, some of the information about neural structures that is presented here is a simplification, quite possibly an oversimplification, of current neurocognitive research. Moreover, although more is being learned about the brain all the time, much about the brain still remains a mystery. While intriguing, current research on the brain doesn't necessarily give us a full and accurate picture of what is actually going on. Secondly, while we can talk about the function of particular brain areas, we shouldn't think of these areas as independent modules with a single function. Each area is interconnected with many other different areas of the brain, and may participate in more than one functional network.   Thirdly, the same or similar information may be used by many parts of the brain. Additionally, general neuronal processes will presumably be similar throughout the brain. For these reasons, the presence of image-schematic structure in a given area of the brain does not necessarily mean that this is the only area that computes this image schema. In fact, it seems reasonable to suppose that the more generally applicable a schema is, the more areas it is likely to "appear" in. Keeping all of these things in mind, we now return to our hypothesis.

How can we go about investigating this hypothesis? Following the line of reasoning presented above, we can start by using existing brain research to try to answer the following questions: (1) Which areas of the brain are active when we walk, run, enter buildings etc.? (2) What sorts of neural circuitry are present in these areas? (3) How might this circuitry support the

sorts of schematic structure we saw in motion descriptions? Further brain research will also be needed; we will suggest ways that such research might test (and likely lead to modifications of) this hypothesis.

Let us start by considering the types of brain activity which occur during self-motion experiences. Although we may not pay conscious attention to what we are doing when we move around, several different functions need to be performed by our brain. We have to execute and monitor motor control routines to make our body move, monitor our immediate environment so we don't run into things while we're moving, and we also need to keep track of where we are so we don't get lost. In order to perform these and other necessary functions, many different parts of the brain will be simultaneously active. Of these active areas, we will want to focus on multi-modal secondary brain areas rather than more primary areas, since, as discussed above, we believe that they have the right sort of circuitry to compute image schemas.

From this set of active areas, we have chosen to focus on two functional networks. First we will look at a network concerned with location and navigational functions, and then at a network related to motor-control functions. We will examine the structure and function of selected brain areas within these networks in order to determine what sorts of structure they may impose on motion experiences. Further, we will consider what sorts of schematic structures might be computed by their neural circuitry, and how such structures may be similar to the path- and manner-related image schemas that appear in motion descriptions.

3.2.   Navigational functions – the hippocampus

While several brain areas are involved in processing spatial information for navigational purposes, we will focus on one area, the hippocampus. As well as being involved in episodic memory, the hippocampus is thought to play a particularly important role in navigation, helping to keep track of current location and to find novel routes within an environment. It has been theorized to function as an allocentric cognitive map, determining an organism's location with respect to objects in the environment rather than with respect to the organism itself. (O'Keefe & Nadel 1978).4 Notice that

this use of a self-to-environment relation to determine location is similar to what is used in motion descriptions containing path information. As we saw, path-related locations are commonly specified via the spatial relation between the mover and some object in the environment (*He ran to/into the house*).

Contained within the hippocampus are "place cells". A given place cell is active only when an organism is in a particular relatively small region of its current environment (the cell's "place field"). Although much of what is known about place cells and the hippocampus' role in navigation is the result of animal studies, similar findings have been made in humans. (Maguire et al. 1998; Ekstrom et al. 2003; Hartley et al. 2003; Hartley et al. 2004).

Place cell activity is related to the presence of certain kinds of environmental information. Significantly for our current endeavor, the informational sensitivities that seem to be exhibited by place cells are similar in many ways to the schematic elements commonly found in path descriptions. Some of the key similarities are as follows:

- The most influential type of information for place cells seems to be that provided by distal sensory cues, particularly stable visual cues. Place cell firing fields do <u>not</u> generally seem to be affected by the movement of small objects within the environment, though Rivard et al. (2004) found that some the firing of some cells seemed to be related to barriers within an environment. In language, the landmarks used to describe the mover's location are usually objects with a fixed location, quite commonly ones that are visible from a distance (e.g. *He walked to the mailbox/tree/store*, but not usually *He walked to the cat*.).

- Distortions of place fields that result from changing the shape and size of the environment suggest that place fields are sensitive to distance and angular relations to boundaries, such as walls. (see Hartley et al. 2004, page 5). Recall that in language, boundaries and walls were seen to be important schematic structural elements of the landmarks used in motion descriptions. For example, in both *He entered the building* and *He ran out of the kitchen,* the landmark's boundaries, in conjunction with other elements of the CONTAINER schema, were used to specify the changing locations of the mover. Additionally, we saw that spatial

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4 In this respect it differs from path integration (originally called "dead reckoning") in which, it is theorized, a mover keeps track of location by relying on cues derived from self-motion (see Etienne and Jeffrey, 2004).

relations terms such as *cross* and *across* utilized schematic structure that involved the geometry of the landmark. In such cases, the geometry of the landmark may be used to differentiate its boundaries, and a mover's current location could be coded with respect to relative distance (and angular relation) to different landmark boundaries. Recall also that Talmy noted that ground (landmark) geometry was one of the basic distinctions made by spatial relations terms.

- Significantly, while place cell activity is related to an entity's location within the environment, it is independent of the entity's orientation (see Hartley et al, p.4). In other words, an organism isn't sensitive to which direction it is facing while at that location. In language, the schematic structure of these landmarks seems to be the same regardless of the mover's orientation to them; a building has the schematic structure of a container whether someone is *entering* it or is *exiting* it.

To summarize, the hippocampus seems to rely on place cell activity to keep track of the organism's location. Place cell activity correlates with certain limited types of information. Place cells seem to be particularly sensitive to distal landmarks and schematic elements of local landmarks (boundaries, in particular). Place cells do not seem to be sensitive to the organism's current orientation in relation to the environment. And, the types of information to which place cells are sensitive seems to be very similar to many of the types of schematic information that commonly occur in path descriptions of motion.

The neural circuitry within the hippocampus effectively imposes a particular kind of schematic structure on motion experiences. This is not to say that the hippocampus is the origin of each of the individual schematic structural elements described above. Object boundaries, for example, may be computed by basic perceptual systems of the kind modeled by Regier. What is significant is that the hippocampus is "selective" about which information it uses to perform its navigational functions. In addition to boundary information, perceptual systems detect many other object properties, such as shape and texture. Other brain areas, such as the parahippocampus (Epstein et al. 2003), are sensitive to a person's orientation relative to the environment. But place cells in the hippocampus do not seem to be sensitive to the entire range of information that is present as we move about. Instead, the hippocampus relies on only certain limited elements of motion experiences in order to perform its navigational functions. Within the hippocampus, then, experiences of moving about in

the world are schematically structured.   Path of motion descriptions evidence similar structure, suggesting that the hippocampus may provide the neural substrate for many of the schemas found in such descriptions.

3.3.   Motor-control elements of locomotion

When we walk or run, in addition to knowing where we are and where we're going, we also have make our body move from one place to another. To do this, we need to execute and monitor motor-control routines. Since locomotor actions such as walking and running are kinds of motor actions, the neural circuitry associated with locomotion will presumably be similar in many respects to the circuitry involved in other types of motor actions. Indeed, imagining locomotor actions has been found to activate cortical regions which are part of "a well-documented neural network associated with the mental representation of motor actions" (Malouin et al. 2003: 56). Descriptions of locomotor actions may therefore express some of the same image-schematic structure as appears in descriptions of other types of motor control actions.   However, recall that the proposed LOCOMOTION schema included some schematic elements, such as gait, which would distinguish locomotion from other types of motor actions. In this section we will focus on these distinctive elements, and the neural circuitry that might compute them.   In order to determine which brain areas might contain such circuitry, we will explore some of the ways that brain activation during locomotion may differ from activation during other types of motor actions.

One difference between locomotion and other motor actions may relate to the somatotopic organization of motor control regions. Within these regions, which group of neighboring neurons is active during a motor-control action depends on which part of the body (feet/legs, hands/arms, teeth/mouth) is used to perform that action. Walking involves foot and leg actions, and these actions have been found to show activation consistent with this somatotopic organization (Sayhoun et al. 2004). The execution, observation, or imagination of actions involving other parts of the body, such as hands (grabbing) or teeth (biting), will each activate other areas (Buccino 2001; Ehrrson 2003). Significantly, recent studies show that reading or hearing language about actions performed by different body parts (mouth, fingers, feet) also produced a pattern of activation that is consistent with such somatotopic organization (Hauk et al, 2004; Hauk and

Pulvermuller, 2004; Tettamanti et al, 2005). Thus, the neural circuitry of somatotopically-organized motor-control regions seems to support schematic specification of the body part used in a motor action. For locomotion and manner of motion verbs, the relevant body part will usually be feet and legs, though some manner verbs (*climb, crawl)* may also indicate the use of hands and arms.

Walking and running differ from many other motor actions in that they involve sequential rhythmic behavior. Selection of a particular gait and/or speed of locomotion may be related to the level of activation in the cerebellar locomotor region. Increased activation within this area leads, in cats, to a change in gait, such as a change from walking to running (see Jahn et al, 2004). In humans, Jahn et al (2004) found greater cerebellar activation for running than for walking or standing imagery. They suggest that increased activation within this region "might reflect the correlation between neuronal activity and speed reported in animal experiments" (p. 1729). Thus the cerebellar region seems to have neural circuitry that relates to speed and gait elements of locomotion. These same schematic elements appear in motion descriptions; as we saw earlier, different manner verbs schematically specify different gaits and/or speeds. We might, for example, differentiate between *walk, stride, jog* and *run* on this basis.

As we perform the locomotor routines involved in walking or running, we need to monitor and react to our immediate surroundings; if there's a hole in the road we want to step over it, not into it. Performance of this function may in part depend on the parietal cortex. Activity in some areas in the parietal cortex seems to be related to the presence in the immediate environment of obstacles that require modification of the current motion pattern (Beloozerova and Sirota, 2003; Malouin et al, 2003). The parietal cortex is thought to be involved in multimodal representations of local space used for the control of limb movements5 (Andersen et al, 1997; Colby & Goldberg, 1999; Rizzolatti et al, 1997). For locomotor actions like walking, where control of the feet and legs is important, the area immediately in front of the feet would presumably be particularly relevant. When the walking surface is smooth and no obstacles are present, relatively little attention needs to be paid to the immediate surroundings and,

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5 The spatial sensitivities of parietal areas are different than those exhibited by the hippocampus. While hippocampal place cells process information about landmarks some distance away from the body (walls, distal landmarks), parietal areas seem to only process information about more proximal landmarks (Save & Poucet, 2000).

consequently, neural activity in these areas would be expected to be relatively low.   But for adverse conditions, such as the presence of obstacles or rough path surfaces, motion may need to be modified, and the level of activation in this area would consequently be higher. In language, manner verbs can also distinguish between situations where no hindrances are present, as in verbs like *stroll, glide*, and *amble*, and ones where gait has been modified, possibly in response to adverse conditions, as in verbs like *trudge, slog, leap, duck*, *stumble* and *crawl*. The particular conditions are not specified, though a "schematic" value may be inferable (e.g. *slog* may indicate some sort of wet or marshy surface).   In the proposed Locomotion schema, the structural element we called "Effort" may to some extent reflect the presence of such adversity, since the amount of effort needed for locomotion is often correlated with the nature of the surroundings. Avoiding obstacles, for example, will presumably require more effort.   Neural circuitry within the parietal cortex may be at least partly responsible for computing image-schematic elements such as the presence of obstacles and related modifications of gait.

In sum, motor-control-related brain areas that are active while we are walking or running are responsive to many of the same sorts of information as are schematically specified by manner verbs. Within somatotopically-organized motor-control regions, different groups of neurons will be active when different body parts (head, hands, feet) are used to perform an action. Activation in the cerebellar locomotor region seems to be related to the gait and/or speed of locomotion. Activity levels in some parts of the parietal cortex seem to be related to the presence or absence of adverse surface conditions or obstacles. Working together, these areas effectively impose a different sort of structure on motion experiences than does the hippocampus. Moreover, many of these same areas have also been found to be active when we are imagining, observing or even talking about such actions. Significantly, the particular types of information associated with the neural circuitry of these areas – body part, gait, speed, and effort or difficulty of motion – are very similar to the schematic parameters specified by manner of motion verbs.   This leads us to propose that these motor control regions may serve as the neural substrate for the image schemas found in manner of motion descriptions.

3.4.   Neural section: summary

Now let us put all this together to tell what we think is a plausible story about motion experiences, neural structure, and the image-schematic structures used in motion descriptions. As we walk or run from one place to another, many different parts of our brain will be concurrently active. Some sub-set of these active areas will have the sort of neural circuitry that computes image-schematic structure. There may well be some degree of "overlap" in terms of what sort of schematic structures are computed by these neural circuits. Many different brain areas, for instance, include object boundaries as part of their computations. However, the schematic structures computed within a given area will differ in at least some respects from those computed in other areas. These differences will presumably be related to what functions an area performs, and what types of information it needs to perform those functions. Working together, these active areas will compute a wide range of schematic structures. We might therefore consider these active brain areas as somehow supplying an "inventory" of different image schemas that structure experiences of walking and running. Notice that such schematic structuring of motion experience occurs independently of the language which expresses these image schemas.

When we talk about motion experiences like walking and running, we activate some of the same neural circuitry as is active during actual experience. These active areas will presumably include the neural circuitry used to compute the above-mentioned "inventory" of image schemas. However, not all motion descriptions will make equal use of this inventory. While the speaker has some discretion as to which schematic elements he chooses to express, the choice will also be guided by the language he is using; languages differ in terms of which schematic elements tend to be or are obligatorily expressed. Of particular relevance to this section, motion verbs in some languages tend to include manner of motion information, while motion verbs in other languages tend to include path of motion information. These two types of information are each associated with the use of a different set of image schemas. And, as we've shown in this paper, these path- and manner-related schemas may each be computed by the neural circuitry of different functional brain networks. Consequently, "manner-predominant" and "path-predominant" languages may differ not only in their utilization of the basic image schema inventory, but also in terms of their underlying neural substrates. In sum, for either type of language we may be using some of the same brain circuitry as is active during actual motion experiences. However, when verbs include path information, we may activate different neural circuitry than when they

include manner information. More specifically, we have hypothesized that the use of path information may correlate with activation in the hippocampus, while use of manner information may correlate with activation of motor-control areas concerned with locomotion. To the extent that these different brain areas also support different types of imagery, it would not be surprising to find that manner verbs are associated with different imagery than path verbs.

While this story seems plausible, it is by no means proven. However, it suggests several directions for future research. The specific hypothesis made here can be tested by conducting research on the patterns of brain activation associated with the use and comprehension of path and manner verbs. We might also investigate the question of what happens when we use more than one kind of image-schematic structure in a sentence. For example, what happens when sentences with a manner verb also include path information? Additionally, image-schematic structures in other domains of experience might be fruitfully analyzed using an approach similar to that shown in this paper.

4. Concluding Remarks

Image schemas are sometimes viewed as abstractions over experiences. However, this is misleading, in that it implies that we start with full, rich representations of experiences and then somehow "abstract out" or extract certain schematic structural elements that are common to all of these experiences. This view doesn't explain how or why we perceive the particular schematic structural elements that we do, nor does it explain how this abstraction process is performed.

Viewing image schemas as neural circuits, however, we see the relation between experience, language and image-schematic structure very differently. If a given brain area or circuit is sensitive only to a few types of information relating to an experience, and is not sensitive to a vast range of other information about the experience, then that area or circuit in effect provides a schematic representation of that experience. If we anthropomorphize this circuit, we might say that all it can perceive about the experience are these few schematic elements. This doesn't necessarily mean that each neural circuit supports a different primitive image schema (if it did it would mean that there were a huge number of primitive image schemas!). The brain is massively interconnected, and the same or similar

information may be used for different functions in many different parts of the brain. Consequently, related image-schematic structures may be distributed across several brain areas. Whenever the neural circuits within these brain areas are active, they may serve to impose schematic structure on the current experience. There are two very important consequences to this. Firstly, because the same neural circuit may be active for many different experiences, it is possible for the same image-schematic structure(s) to be imposed upon a large variety of experiences. This explains why we can "find" the same image schema in many different experiences. Secondly, for a given experience, many different brain areas and neural circuits will be active. Thus, more than one type of image-schematic structure may be imposed upon that experience. This explains why we can "find" more than one type of image-schematic structure in a given experience. Importantly, the image-schematic structure imposed upon experience exists independently from the language that expresses it. Consequently, languages may vary in terms of which elements of schematic structure they tend to express. Additionally, words may link with different complex combinations of related image-schematic structures. Thus, the image-schematic structure that we observe both in experiences and in language about those experiences are both natural results of the way the brain is structured.

Extensive cross-linguistic variation in spatial relations terms and motion descriptions has sometimes been taken as an indication that it is misguided to spend time looking for neural structures associated with primitive image schemas. We believe this attitude is itself misguided. To a large extent this position seems to be based on a notion that image schemas are concepts associated with individual words. Since such concepts do not seem to be universal, there seems to be no point in looking for universally available structures, neural or otherwise. However, while individual spatial relations terms, for example, may evidence different types of complex schematic structures, we've seen that they appear to use only a limited set of basic distinctions or primitive image schemas. It is this limited, presumably universally-available set of image schemas which we believe to be associated with language-independent neural structures. Furthermore, many linguistic theories do not attempt to link linguistic structure to neural structure. Sometimes this is because neither image schemas nor a detailed understanding of the brain are considered critical to an understanding of language or linguistic diversity. Other times it is justified by saying that we just don't know enough about the brain, its structure, and how it may affect

language to seriously take neuroscience into consideration when making linguistic theories. It is true that much remains to be learned about the brain. However, as we have shown in this paper, neuroscience matters. It leads us to choose Talmy-Langacker style theories over the Nijmegan approach to linguistic diversity. Moreover, it leads us to a deeper understanding of image schemas and their relation to experience, language, and the brain.

Coda

- Linguistic structure reflects brain structure.
- Linguistic structure is schematic (image schemas, force-dynamic schemas, aspectual schemas, and so on) because the corresponding brain regions each perform limited, small-scale computations.
- Linguistic schemas can form complex superpositions because the corresponding brain structures can be active simultaneously.
- Complex linguistic structures that vary widely are each made up of the same ultimate universal primitives because we all have the same brain structures that perform the same computations.
- Linguistic structure is below the level of consciousness because the brain structures that compute them are unconscious.
- Abstract schematic structures are not learned by a process of abstraction over many instances, but rather are imposed by brain structure.
- Image schemas are created by our brain structures; they have been discovered, not just imposed on language by analysts.
- Cognitive linguistics isn't cognitive linguistics if it ignores relevant knowledge about the brain.

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