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Flexible foundations of abstract thought: A review and a theory

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

When observing a person talking about an abstract idea, say, a psychology professor describing a particular theory, we can often see that her hands depict in the air the concepts she is mentioning as if they were solid, concrete objects (McNeill, 1992). She might, for example, move her hand upwards as if holding a ball-like object. Simultaneous speech make clear that these solid objects are used to refer to the same concept that is being mentioned. For example, the ball is "presented" to the audience as the speech introduces the name of the theory. Even more interestingly, the solid ball also seems to participate in reasoning involving the concept, as when the theory is compared to a rival theory, held as another ball in the other hand. The professor might then stare to one imaginary ball, then to the other, and compare their weights while she explains why one theory outperforms the other in its fit to available data.

Why are all these concrete concepts called upon when talking about abstract meaning? Are concrete experiences of moving and interacting with the physical world an integral part of abstract meaning? Or are they a more or less optional component that can be called on demand depending on the requirements of the situation (say, for improving understanding in the addressee or performing certain reasoning tasks)?

This question is the Symbol Grounding Problem (Harnad, 1990), and it constitutes a central topic in cognitive science (Barsalou, 1999; Glenberg, 1997; Harnad, 1990; Johnson-Laird, 1983; Lakoff & Johnson, 1999; Evans, Bergen & Zinken, 2008): how are concepts grounded in the external world? How is the internal representational machinery of the mind brought to bear on the objects and events that surround the individual? Within this general frame, many authors agree that the grounding of abstract concepts constitutes the hardest part. How can we think about things we have never experienced? How can the concepts of DEMOCRACY, FUTURE, or CONCEPT be entertained, let alone their references resolved?

The notion of embodiment has been offered as a possible solution to this problem. In what follows we first outline the version of embodiment that will be scrutinized in this paper, based on the idea of conceptual metaphors, what we will call the Solid Foundations View. We then identify the problem of cognitive flexibility as one of the most challenging questions for the Solid Foundations View, and undertake a literature review of research from several different traditions which can be related mostly to primary conceptual metaphors. We will keep the review focused on tasks in-

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volving literal or highly conventional language, including numbers, or without a linguistic component. Related research on figurative language processing will be mentioned only in passing.

Contrary to expectations from this view, available evidence shows a surprising degree of flexibility in conceptual metaphoric mappings, and points to a number of mediating factors. Cognitive flexibility opens questions regarding how specific mappings are selected and used in particular occasions. The main goal of the present paper is to offer an answer to these questions that grants cognitive flexibility a central theoretical role, instead of treating it as a nuisance. A main consequence of this approach will be to bring working memory to the explanatory forefront, leaving semantic long term memory in the background, just the opposite situation to what is currently the norm in the embodiment literature.

We show how the theory can integrate prior results, points to several factors that mediate the flexibility in the manifestation of conceptual projections, and generates several new predictions. We then draw on our own research to provide support for the theory. Finally, we end with a discussion of the implications of the theory for the issues of the acquisition of conceptual metaphors, their cross-linguistic and cross-cultural variations, and the Symbol Grounding Problem.

Figure 1.- The Solid Foundations View of abstract concepts (photograph by wallyq, some rights reserved).

The Solid Foundations View of Abstract Concepts

The Solid Foundations View of abstract concepts has its origins in Conceptual Metaphor theory, which emerged within cognitive linguistics with a stronger focus on representation than on processing (Lakoff & Johnson, 1980, 1999; Gibbs & O'Brien, 1990; Johnson, 1987). In this view, concrete conceptual domains, which arise by direct experience in interaction with the world, are characterized by their image schematic structure (see also Mandler, 1992). Image schemas are perceptuo-motor gestalts such as SOURCE-PATH-GOAL, which arise from repeated situations in which movement from a source point to an end point is observed, experienced or imposed onto something. Other proposed image schemas include CENTER-SURROUND, CONTAINMENT, or BALANCE (Johnson, 1987). Image schemas provide relational structure to concrete conceptual domains. All other concepts are hypothesized to be structured through metaphoric mappings from these concrete domains. Such mappings arise also because of experienced correlations between the processing of the concrete and the abstract domains.

As an example, the domain of time (at least in one of the meanings of the polysemous term "time", see Evans, 2004) is proposed to borrow extensively from the domain of space, such that time is understood as the PATH along which the observer moves from one SOURCE location in the back (the past) towards another GOAL location in front (the future). This primary metaphor has been termed TIME IS MOTION, and arises from repeated correlations between the experience of motion and the passing of time. Some other proposed primary metaphors are MORE IS UP, HAPPY IS UP, or KNOWING IS SEEING (Lakoff & Johnson, 1980, 1999), which are embodied in experienced correlations between height and amount of substance, between body posture and emotion (positive or negative), and between the act of seeing and the experience of knowing. More complex concepts are in turn built up metaphorically through combinations of metaphors, such as, e.g., LOVE IS A JOURNEY or THEORIES ARE BUILDINGS.

Embodiment is thus something akin to the foundations of a building. Under this view, the human conceptual apparatus may look like the Empire State Building (Figure 1), a rock-solid structure where upper (more abstract) floors are supported by lower (more concrete) floors, which ground the whole structure firmly on the experiential terrain. The progressive bottom-up support is both intended as a metaphor for the adult conceptual system and for its ontogenetic development (Lakoff & Johnson, 1980, 1999; Mandler, 1992). This is the central tenet of the theoretical family that we refer to as the Solid Foundations View. Conceptual Metaphor Theory constitutes its strongest formulation.

In this view, all meaning is embodied in the sense that it all refers more or less directly to basic image schemas, which are abstracted in turn from perceptuo-motor experiences. There is a strict directionality implied here: more abstract domains borrow structure from more concrete domains, but concrete domains do not borrow from abstract domains. We will refer to this assumption as the Strict Directionality Hypothesis heretofore. It should be noted that, under this formulation of the hypothesis, it implies both an ontogenetic asymmetry (more abstract concepts develop from more concrete concepts) and a representational asymmetry (more abstract concepts are represented in terms of more concrete concepts).

The power of metaphoric mappings for substantiating abstract thought lies in their ability to guide inferences and construct new meaning. To stay with the example of time, our bodily experience of passing time affords very few inferences by itself. Once time is mapped onto spatial motion, the imported structure allow a much richer set of inferences, i.e., one can ask what event is farther away in the future or in the past, whether it is possible for events to travel in circles and occur again in cyclic fashion, and so on. Hence, metaphoric structure helps reasoning and problem solving. Finally, conceptual metaphors allow extending meaning along novel lines which are consistent with the established mapping, as when we wonder whether we will be marching, stumbling or sliding into the future.

The original linguistic evidence stemmed from the analysis of patterns of idiomatic use in language. Lakoff & Johnson (1980) observed that conventional expressions can be grouped together in families which suggest a common underlying metaphoric structure. For example, sentences like “we are years ahead of them”, “that was a long time back”, or “he is advancing quickly towards a great future”, all share the underlying TIME IS MOTION metaphor. This systematicity was unexpected from the standard semantic analysis of idioms, which sees them as frozen complex lexical items whose meaning must be listed as a whole in the mental lexicon (Cruse, 1986). Even more convincing was the fact that these hypothetical conceptual metaphors would allow idiomatic meanings to be extended in novel ways (as in the phrase “a remnant from a misty past”) without compromising their comprehensibility. They also noted that it is very often the case that people speak about an abstract concept in terms of a more concrete one, but rarely they do it in the opposite way.

The analysis of polisemy provided another important source of support for these original insights. In the standard analysis, polisemy is captured by listing different senses of a word, as if they were just homonyms (e.g., Katz & Fodor, 1963; Cruse, 1986). However, meaning extensions of polisemous words often follow the lines established by conceptual metaphors (see, e.g., Tyler & Evans, 2001). These lines seem to be also important organizing principles for semantic change over time (Sweetser, 1990).

Gesture also provides many examples of abstract concepts being instantiated as concrete examples of image schemas, both in spontaneous gestures made along spoken language (McNeill, 1992; McNeill & Duncan, 2000; Núñez & Sweetser, 2006) and as stored lexical items in signed languages (Taub, 2000, 2001).

However, given its observational nature, these kinds of evidence, although intuitively compelling, cannot be taken as definitive evidence for the psychological reality of conceptual metaphors (Murphy, 1996, 1997). So far, the only argument for the proposed causes of linguistic patterning (regularities of thought) relies on theoretical parsimony. Parsimony, though, is only a heuristic strategy in science. In order to establish a causal relation between thought and language, it is necessary to use experimental methods. However, the Conceptual Metaphor View is not stated as a processing model, and as such, it cannot make predictions on performance in behavioural tasks of the kind used in psychological experiments. Therefore, a psychological version of it was devised by Boroditsky (2000), the Metaphoric Structuring View.

The Metaphoric Structuring View adopts the central idea of the progressive building of more abstract (less clearly delineated) conceptual domains on the foundations of more concrete (clearly delineated) domains. From there it follows the expectation of interactions between the online processing of concrete and abstract concepts. Boroditsky (2000) also accepts the Hypothesis of Strict Directionality from concrete to abstract domains, and uses it to predict the shape of that interaction. She distinguishes two versions of Metaphoric Structuring. The Strong Version assumes that the source concrete domain is automatically activated by aspects of the situation, and it is then used to structure the abstract domain, so framing its understanding and reasoning about. The Weak Version maintains that, after repeated use, the relational structure of the source domain may be stored at the abstract domain, allowing the processing of the latter without having to activate the former. Under the Weak Version, once a conceptual metaphor is well established, no further influences of the processing of the abstract domain are expected on the processing of the concrete domain. Processing the concrete domain should influence concurrent performance based on the abstract domain, but the opposite should not hold. Boroditsky (2000) observed asymmetrical priming effects, which have since been replicated in several studies (e.g., Casasanto & Boroditsky, 2008; see discussion below) and thus rejected the Strong Version.

Although agreeing on the basic structuring of the conceptual system, it is important to note that Boroditsky (2000, and in later writings) does not sustain the ontogenetic view posed by Lakoff and Johnson (1980, 1999). Under her view, the determinant factor for the development of metaphoric mappings is language, and not experiencial correlations between the processing of the concrete and abstract domains. The metaphorical expressions present in language motivate the generation of analogies and guide the mapping of structure across concrete and abstract domains. Therefore, although the Weak Metaphoric Structuring Version is mainly related to the online processing of abstract concepts, it comes associated to an ontogenetic view of its own that places language at the origin of conceptual metaphors.

A final, intermediate version has been recently put forward by Casasanto (2008; Casasanto & Boroditsky, 2008; Casasanto, in press), which we will call the Integrated Metaphoric Structuring View. It accepts the tenets of the Weak Metaphoric Structuring View, but suggests that both experiential correlations and linguistic metaphors play a role in the development of conceptual mappings. Perceptuo-motor experiences provide the ground for universal conceptual metaphors and language enters the picture later to strengthen some mappings and weaken others. So far, only one clear dissociation between these two sources of conceptual mappings has been reported (Casasanto, in press): whereas right-handers associate positive emotional valence with right space and negative valence with lefit space, in agreement with both linguistic-cultural conventions and bodily experiences, left-handers show the opposite association. The mapping in left-handers must arise, therefore, only from perceptuo-motor experience, against the tide of language and culture. Figure 2 shows the family tree of the Solid Foundations View.

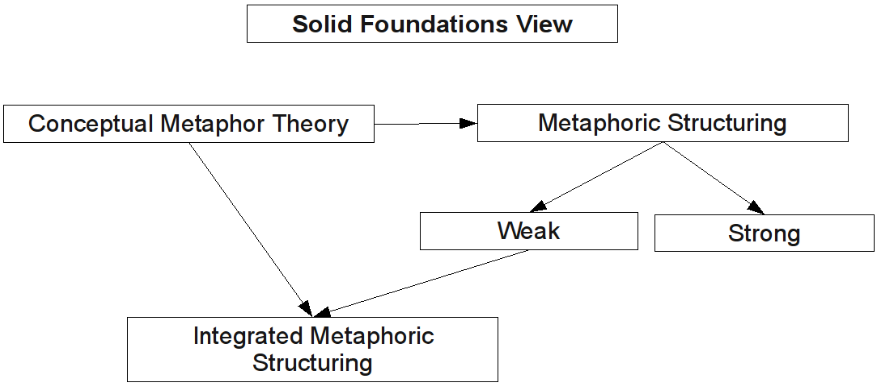

Figure 2.- Family tree of the Solid Foundations View

Summing up, the Solid Foundations View seems to provide a neat description of how abstract concepts are grounded, by resorting to mappings from more concrete concepts, and suggests two possible mechanisms for their acquisition: experiential correlations and linguistic influence. But before we turn to its problems, a quick note is in order about its relation to the other main tradition in the study of the embodiment of abstract concepts, the Simulation View. This approach posits that all concepts are represented by means of the enactment of detailed mental simulations, with extensive involvement of perceptuo-motor representations (Barsalou, 1999, 2003; Barsalou, Simmons, Barbey & Wilson, 2003; Glenberg, 1997; Gibbs, 2003). Most of the research within this tradition has been concerned with the processing of words and sentences with concrete meanings (see Zwaan, 2004, for a review). Regarding abstract concepts, Barsalou (1999; Niedenthal, Barsalou, Winkielman, Krauth-Gruber & Ric, 2005) has argued that their processing can be accounted for with very little resort to metaphor. Instead, the content of an abstract concept is constituted by concrete concepts and basic image schemas which are part of the perceptual, motor and introspective activations that form its experiencial basis. That is, abstract concepts are directly represented in terms of complex combinations of concrete concepts (with the important addition of introspective events within this category). This is an even stronger position than the Strong Metaphorical Structuring View, one that fails to see a representational difference between concrete and abstract levels. Strict directionality effects argue, therefore, against this position. However, Barsalou (1999) was careful not to deny the possibility of metaphoric structuring for some abstract concepts, and a more prominent role has been acknowledged by other proponents of the Simulations View (e.g., Zwaan, 2004).

The problem of cognitive flexibility

The picture laid by the Solid Foundations View is complicated by the fact that many primary conceptual metaphors can be used to structure a given abstract concept in different occasions, both by a single individual and across languages and cultures. Conceptual Metaphor Theory suggests that abstract concepts are grounded through experiential correlations in primary metaphors, which in turn are grounded in perceptuo-motor correlations, such as watching an object to move from one location to another. Such experiences are supposed to be determined by the characteristics of human bodies and their perceptual and motor systems, as well as by the characteristics of the environment with which humans interact. Therefore, image schemas should be basically universal. From there, it arises the expectation of universal primary metaphors (see Rakova, 2002, and Koveczes, 2005, for discussions). By including the possibility of language influences on conceptual mappings, the two current versions of Metaphoric Structuring (Weak and Integrated) are, in principle, better equipped to deal with cross-linguistic variability, but not with within-subject moment-to-moment variability. Another expectation that follows from the Solid Foundations View is that the influence between the processing of concrete and abstract domains should be asymmetrical, with a stronger influence from concrete to abstract and small or null influence from abstract to concrete. Available data also cast doubt on this prediction. Finally, the fact that all of them assume associative learning mechanisms also leads them to expect gradual acquisition of abstract concepts through repeated practice. This contrasts with the surprisingly fast learning rate that sometimes is attested.

As the upcoming review will reveal, there is an impressive degree of flexibility in conceptual mappings, both within and across languages and cultures. Alternative conceptual metaphors can be selected with high ease and speed, as well as old mappings replaced by new ones. The directionality of the cross-domain effect can also be altered. The present review will also point out several factors which seem to mediate the manifestation of that cognitive flexibility in behaviour. Because of its extensive study, we will start this review focusing on the conceptual domain of time, and then expand the conclusions by looking at other conceptual domains.

Cognitive flexibility in the domain of time

Within-subject flexibility

The conceptual metaphor of time which has so far received most attention in the literature maps past to locations in the back of the observer, future to locations in her front, and time to forward motion from past to future. This mapping has been termed the "ego-moving" metaphor (Clark, 1973). However, conventional language often shows the use of a different time metaphor, the "time-moving" metaphor, as in the sentence "Christmas is quickly approaching". In this mapping, time is also motion along a front-back PATH, but it is time units what move. The observer stands still as future time units approach her, pass her by and proceed into the past. Of central importance, only one mapping seems to be used to structure time in each given occasion, a choice which can have non-trivial consequences for thought. For example, the sentence "Next Wednesday's meeting has been moved forward two days" is ambiguous (McGlone & Harding, 1998; Boroditsky, 2000). If the listener uses the ego-moving metaphor, the meeting will be held next Friday. If the time-moving metaphor is used, the meeting is scheduled for next Monday. The chosen mapping helps framing the problem, and therefore affects its solution.

There is also supporting experimental evidence. McGlone and Harding (1998) presented a context of sentences referring to the time of events from either the ego-moving or the time-moving perspective. Participants judged whether each sentence was true or false with respect to a given temporal reference. When the last sentence changed perspective, decision times increased. In a second experiment, prior context affected how an ambiguous sentence such as "The meeting has been moved forward two days" was interpreted. Boroditsky (2000) obtained similar results using spatial primes in which a person moves toward an object (ego-moving) or an object moves toward a person (time-moving). Gentner, Imai and Boroditsky (2002) observed a congruency effect in reaction times in a task in which participants read a context written from one or the other perspective, and judge whether the mentioned event is past or future with respect to a reference event. Boroditsky and Ramscar (2002) extended the primes to actual experiences of motion by asking the ambiguous "meeting" question to people at different points of a trip by flight, train or along a lunch line, and showed that the spatial experience of motion is able to prime the choice of an ego-moving perspective as long as people are actively paying attention to those spatial experiences.

Recently, a third type of spatial mapping has been emphasized by Núñez and Sweetser (2006), Núñez, Motz and Teuscher (2006) and Moore (2006). Núñez et al named it the "time reference point" (time-RP) metaphor. When it is used, the sequence of events does not refer to any observer co-located with the present, but only to the order of events in itself (as in expressions like "Monday precedes Tuesday"). Núñez et al (2006) were able to prime the use of a Time-RP perspective by means of displays of sequences of cubes moving horizontally, without including any ego that could be used as reference point. This mapping can be applied, in principle, to any spatial axis (front-back, left-right or up-down), as long as anteriority is mapped to the beginning of the sequence of events and posteriority to subsequent positions. However, gestural evidence obtained by Núñez and Sweetser (2006) suggests that the left-right spatial axis is often used to ground the Time-RP metaphor, which takes us to as yet another variant of the question of flexibility.

An interesting consequence of the experimental research on conceptual metaphors has been the discovery of mappings that are not attested in linguistic expressions, and therefore, have escaped the attention of linguists. A chief example is the TIME IS MOTION metaphor that maps time onto the left-right spatial axis, instead of the more investigated front-back axis. In his review of cross-linguistic metaphors for time, Radden (2004) concluded that there seems to be a total lack of linguistic conventions that refer to the left-right dimension in speech about time in any language. Signed languages seem to be the only exception to this rule (Emmorey, 2001). In contrast, we are all used to the conventional association of time to the horizontal axis in graphs, increasing from left to right. Comic strips and written language also flow from left to right in English, Spanish, and many other languages.

Tversky, Kugelmass and Winter (1991) asked English, Hebrew and Arab children to place three stickers on a paper to represent triads of concepts. Some of these concepts were events organized along time, such as breakfast-lunch-dinner. English children were extremely consistent in placing the three stickers along a horizontal line with a left-to-right progression of events (see also Koerber & Sodian, 2008, for analogous results with German children). What could be the experiental basis of such a left-right temporal mapping? In the Tversky et al (1991) study, Arab children were as consistent in mapping events to space in a right-to-left manner, which points to exposure to reading-writing direction and other graphical conventions as a chief candidate. (Hebrew children performed somewhere in between, what the authors adscribed to their greater exposition to English and other left-to-right orthographies.)

Recent studies have replicated the left-right effect with less explicit tasks. Núñez and Sweetser (2006) observed that gestures for ordered sequences of events were always from left-to-right in speakers of Aymara and Spanish. Santiago, Lupiáñez, Pérez and Funes (2007) presented Spanish adverbs and tensed verbs referring to past or future at left or right positions of a computer screen. Participants judged whether the words referred to past or future by pressing a left or a right key. Latencies were faster when past words were presented on the left or responded to with the left key, whereas the reverse was true for future words. Recent work using analogous procedures suggests that visual narratives such as movie clips (Santiago, Román, Ouellet, Rodríguez & Pérez-Azor, 2008) and short temporal intervals (Vallesi, Binns & Shallice, 2008) are also represented as running from left to right in the mind. Ouellet, Santiago, Israeli and Gabay (in press) have also shown that Hebrew speakers show a reversed right-to-left mapping. Furthermore, Weger and Pratt (2008) and Ouellet, Santiago, Funes and Lupiáñez (in press) have been able to show that the mere activation of the concepts of past and future by means of centrally presented words facilitates the processing of subsequent stimuli presented at left and right locations, respectively.

So far, no studies have addressed whether the ego-moving or time-moving perspectives are equally applicable to the left-right movement of time, but nothing seems to prevent it. Thus, the reviewed evidence suggests that, when time is conceptualized as motion in space, it may move along the front-back and left-right axes, and taking three different perspectives: ego-moving, time-moving and time-RP.

Are these really different conceptual mappings? As Lakoff and Johnson (1980, 1999) pointed out, the ego-moving and time-moving metaphors are just a figure-ground reversal of each other, a frequent phenomenon attested in many other metaphor pairs as well as in literal motion. This argument can be extended to the time-RP metaphor, which would result from taking the perspective of an observer located outside the sequence of events. Even the left-right TIME IS MOTION metaphor could be seen as a minor derivation of the same underlying schema and, perhaps, be explained by an integrated Conceptual Metaphor account. Nevertheless, it is easy to find in language other common metaphors for time which are radically inconsistent with the TIME IS MOTION metaphor, such as TIME IS MONEY. This latter metaphor forms itself a complex with other consistent metaphors, such as TIME IS A SUBSTANCE (as when asking “how much time do you have?”, Lakoff & Johnson, 1980). Temporal metaphors, therefore, show an impressive degree of flexibility within a single individual, language and culture.

Cross-linguistic and cross-cultural flexibility

Within-subject flexibility is coupled with wide cross-linguistic and cross-cultural variation. Continuing with the TIME IS MOTION metaphor, languages and cultures differ in their preference for the use of some spatial axis over others. Moreover, sometimes these preferences are variations of the TIME IS MOTION metaphor, whereas some other times they are mediated by inconsistent metaphors.

Linguistic and anthropological evidence regarding the horizontal front-back axis suggests that speakers of English, Spanish and many other languages (see Malotky, 1983, for Hopi; Alverson, 1994, for Mandarin, Hindi and Sesotho; Ozçaliskan, 2003, for Turkish; see Radden, 2004, for a review) find intuitively compelling that future should be located in front of us and past behind, because we move in space towards locations that will be reached in the future and leave behind the places visited in the past. In contrast, many languages place the future behind and look ahead to the past. This mapping is common in some South American languages, and it seems to be mediated by a non-spatial metaphor, SEEING IS KNOWING: the past is something already known, and it can therefore be “seen” clearly, whereas the future is always a possibility state which cannot be “seen” definitely (see Núñez & Sweetser, 2006, for Aymara; and Klein, 1987, for Toba; there is also some evidence that Hawaiian is also within this language type: Karme'eleihiwa, 1992, cited in Clifford, 2004).

The vertical spatial axis is also used by some languages to express time, at least as an option. English resorts to this axis in expressions like "Christmas is coming up" (Lakoff & Johnson, 1980). There is a time metaphor in Zapotec in which the days and months increase upwards in the vertical dimension, so it is common to refer to the prior month as the down month and to the next month as the up month (MacLaury, 1989). This past-down future-up mapping is probably mediated by the conceptual metaphor MORE IS UP and its experiential basis in image schemas of growing pile size as matter accumulates (Lakoff & Johnson, 1980). Boroditsky (2001, citing Scott, 1989) asserts that Chinese also has a vertical time metaphor, but in the opposite direction, past being up and future down. No image schematic basis for such a mapping are offered, although it might be based on writing direction.

Finally, as mentioned above, the left-to-right mapping of time is attested in conventional linguistic usage only in signed languages (Emmorey, 2001). That this mapping is based on reading habits and graphic conventions is supported by the fact that Jordanian Sign Language conventionally uses a right-to-left temporal mapping instead (Emmorey, 2002). Experimental evidence in the same direction is provided by Tversky et al (1991, see above).

A sizeable literature now supports that reading direction and graphical conventions constitute an important source of perceptuo-motor experiences which may be used to ground conceptual domains. They exert subtle influences on perception (Dreman, 1977), attention (Spalek & Hammad, 2005), motor control and memory (Nachson, 1981), and preferences for physical stimuli (McManus & Humphrey, 1973). Such an effect seems to extend into the conceptual realm:

English speakers have a left-to-right bias when thinking of the agent and patient roles of a sentence: the agent tends to be imagined to the left of the patient. Moreover, actions like “push” or “pull” tend to be imagined flowing from left to right (Maher, Chatterjee, Gonzalez-Rothi & Heilman, 1995; Chatterjee, Maher, Gonzalez-Rothi & Heilman, 1995; Chatterjee, Southwood & Basilico, 1999; see also Rinaldi & Pizzamiglio, 2006, for related evidence). The association of this bias to reading direction has been shown by Maas and Russo (2003), comparing adult native speakers of Arabic and Italian, and Dobel, Diesendruck and Bölte (2007), comparing adult and preschool speakers of German and Hebrew. However, there are also two published studies which fail to replicate this result: Barrett, Kim, Crucian and Heilman (2002) with right-to-left vertical Korean readers, and Altmann, Saleem, Kendall, Heilman and Rothi (2006) with Arab readers.

Finally, there is also some evidence suggesting cross-linguistic variation in perspective use: Dahl (1995) argues that Malagasy does not use the ego-moving perspective at all.

Sometimes, cross-linguistic differences are a matter of degree. For example, Levine (1997) describes wide, but gradual, variations in the use of the TIME IS MONEY metaphor across the world's cultures. Another example is provided by English and Greek, both of which show the use of the TIME IS MOTION and TIME IS A SUBSTANCE metaphors in conventional language, but the former predominates in English and the latter in Greek (Casasanto, 2008).

Because of its reliance on universal perceptuo-motor experiences as the most basic grounding of abstract concepts, cross-linguistic and cross-cultural flexibility is unexpected from Conceptual Metaphor Theory. However, as mentioned above, the two Metaphoric Structuring Views (Weak and Integrated) can account for linguistic relativity effects. Boroditsky (2001) proposed that language may influence the selection of image schemas from the concrete domain that are used to structure the abstract domain in a given occasion. As repeated use produces those schemas to be independently stored within the abstract domain, language habits may affect which schemas are finally selected to structure the target domain. In sum, how people talk may affect how people think. Consistently with this assertion, Boroditsky (2001) showed that vertical spatial primes were more effective than horizontal primes to affect a temporal judgment task in Chinese than in English speakers (but see Chen, 2007, January & Kako, 2007, and Tsé & Altarriba, 2008, for three failures at replicating this result). Casasanto (2008) describes a study which compared English and Greek speakers in the ability of the length of a growing line or the amount of water in a filling container to bias estimations of the duration of the event. Coherent with the predominant linguistic patterns of their languages, English speakers' time estimation was affected by length and unaffected by quantity, whereas the opposite pattern was observed for Greek speakers.

Although this is suggestive evidence for an effect of language on conceptual organization, these data pose a logical problem for both Metaphoric Structuring Views, as they are now faced with explaining how those conceptual mappings get initially into language. One possibility comes from the “career of metaphor” hypothesis proposed by Bowdle Gentner (2005) in the context of metaphor comprehension. They proposed that novel linguistic metaphors (e.g., “a ballerina is a butterfly”) are initially processed as literal comparisons (“ballerinas are like butterflies”), which implies the simultaneous activation of source (butterfly) and target (ballerina) concepts and the alignment of their relational structures and content. With repeated use and conventionalization, an abstract category is created that refers directly to the metaphorical meaning of the target concept (something that moves delicately tracing beautiful figures). Thereafter, metaphoric statements are understood as categorizations (ballerinas are something that moves delicately tracing beautiful figures), often making little contact with the source concept from which the new category was abstracted (butterflies). In this argument, ballerina and butterfly can be readily substituted by time and space. Metaphoric mappings that occur frequently in language can lead to novel conceptual metaphors. Once conventionalized, they can be processed on their own terms, without activating the source domain (see consistent evidence by Gentner & Boronat, 1991, cited in Gentner et al, 2002, and Keysar, Shen, Glucksberg & Horton, 2000). Though attractive, this hypothesis is in need of closer scrutiny. How conceptual mappings get initially into language remains so far an open question for these views.

Flexibility in the directionality of the cross-domain mapping

Prior sections show that wide cognitive flexibility is attested in temporal conceptual metaphors, both within the individual and across languages and cultures. Moreover, it is also possible to make a case for flexibility in the directionality of the cross-domain influence of space and time. Studies of the TIME IS MOTION metaphor have provided what seems strong support for Strict Directionality. Boroditsky (2000) used drawings and sentences depicting either the ego-moving or the object-moving perspective for both spatial motion and temporal “motion”. After seeing one of the primes, participants responded to a spatial or temporal version of the ambiguous “meeting” question. She found that spatial primes were effective in biasing both spatial and temporal reasoning, whereas temporal primes were only effective for temporal targets (see also Kemmerer, 2005, for related neuropsychological evidence).

Casasanto and Boroditsky (2008) provided even more convincing evidence using tasks with no linguistic component. Building upon prior developmental observations by Piaget (1927/1969), they presented growing lines of varying lengths and durations, and asked their participants to estimate either spatial extent or duration. Consistent with the Hypothesis of Strict Directionality, the length of a growing line affected its perceived duration, but there was no influence whatsoever of growing time on perceived line length. In search of an influence of time on space, these authors also used moving dots and stationary lines of varying lengths, but the pattern of results remained constant.

However, Teuscher, McQuire, Collins and Coulson (2008) observed priming effects from both spatial and temporal sentences on ERPs time-locked to a subsequent spatial display showing movement of an object towards a schematic person or viceversa. Space-space priming produced an early ERP component, and more importantly, time-space priming generated a later semantic component. Moreover, the studies by Weger and Pratt (2008) and Ouellet, Santiago, Funes and Lupiáñez (in press) found effects of centrally presented past and future words on the subsequent spatial discrimination of stimuli presented at left or right locations. These studies showcase effects of the processing of the abstract conceptual domain on the concrete domain and, therefore, stand against the Strict Directionality Hypothesis.

Finally, two old phenomena from the field of psychophysics, with the rather uninformative names of Tau and Kappa effects (see Jones & Huang, 1982, for a review), suggest that it may be possible to find effects of time on space in tasks which are very similar to those used by Casasanto and Borodistky (2008). Tau and Kappa effects have been most often tested in conditions in which three succesive discrete stimuli are presented at different points along an imaginary line, defining two spatial and two temporal intervals. The most common task is to adjust either the location or the time of the central stimulus until both spatial or temporal intervals appear equal to the observer. The Kappa effect (Cohen, Hansel & Sylvester, 1953) consists in the influence of the spatial intervals on the perceived temporal intervals, and is therefore consistent with the Strict Directionality Hypothesis. When the first spatial interval is longer than the second, participants lengthen the timing of the central stimulus, and the result is an overestimated first temporal interval with respect to the second interval even though their goal is to make them equal. The Tau effect (Helson & King, 1931) is the mirror image of the Kappa effect: when asked to make both spatial intervals equal, their durations produce corresponding shifts in the spatial estimations. The Tau effect would thus seem to contradict the null time-to-space influence observed by Casasanto and Boroditsky (2008). As Casasanto and Borodistky (2008) argue, it is still unclear whether this contradiction is real or just an artifact from small differences in the methods used. As with so many other questions left open by this review, more research is needed.

It is important to note that, by letting language to take a guiding role in the selection of conceptual mappings, the two Metaphoric Structuring Views also open a possibility for the structure of the abstract domain to affect processing about the concrete domain. If the abstract domain is talked about in terms of the concrete domain, then its structure may be used to organize thinking about the concrete domain. It is possible to talk about space *qua* time, as in "The station is only five minutes away", although the reversed mapping is way more frequent (Boroditsky, 2001; Casasanto & Boroditsky, 2008). This view, therefore, also promotes a weaker version of cross-domain influences, one which we will call the Lenient Directionality Hypothesis. Under this view, asymmetric influences across domains are expected not because of the progressive building of abstract domains from more concrete domains. Instead, they may result simply because it is more common to talk about the abstract domain in terms of the concrete one than the opposite. Of course, this frequency difference may well have deep roots in the conceptual building of the domain of time from the domain of space... or not. Anyhow, the Lenient Directionality Hypothesis opens the possibility of finding effects of time on space under some circumstances: when people talk more often about the concrete domain in terms of the abstract domain than the opposite. Under the typical situation in which the concrete domain predominates over the abstract in linguistic patterns, asymmetrical but not necessarily strictly directional influences are expected (Casasanto & Boroditsky, 2008). The problem is to submit this hypothesis to a fair test, as it is necessary to show that the processing of both domains is equally accurate before assessing the size of the cross-domain effect in each direction, a control that is missing from most relevant studies.

Quick learning of new mappings

A final kind of flexibility in conceptual metaphors has to do with the speed at which new mappings can be acquired. Current Metaphoric Structuring Views suggest that an associative mechanism working through repeated uses of the same mapping increases the probability of activating it again the next time the conceptual domain is processed, leading to the establishment of habits of thought. The more practised a mapping is, the stronger the habit. As a corollary of this position, stronger habits should show an important resistence to change, and only extended practice with new mappings may be able to overcome them. However, this is far from being the case.

Both Boroditsky (2001) and Casasanto (2008) describe experimental studies in which they trained English participants to think about time using a new conceptual mapping. Although both report comparable results, the former study provides a clearer case, as English speakers were trained to use a past-up future-down mapping which is never attested in the English language. The results showed that only 90 training trials (one sentence per trial) were enough to vanish the horizontal priming effect characteristic of untrained English participants and to make themindistinguishable from native Chinese speakers in the spatial priming task. Such results are in starkling contrast with Boroditsky's (2001) own data (Experiments 1 and 2), which were obtained from Mandarin-English bilinguals attending college in the US, that is, after many years of inmersion into English. Actually, the main predictor of the typically Chinese vertical bias was the age of English acquisition, and not the length of English exposure. If about 10 years of intensive experience with English metaphors are not able to turn Mandarin speakers into English speakers, how is it possible that 90 trials suffice to turn English speakers into Mandarin speakers?

We contend that these results are unexpected from the workings of an associative mechanism, although the authors of those studies defended that they are. In the sections below, we will see more examples of quick learning of new mappings in conceptual domains other than time. The learning mechanism must be of a kind that allows much faster learning than usual associative mechanisms do. A category induction mechanism of the kind proposed by Bowdle and Gentner (2005) may make a better job, as it is known that new categories can be formed on-the-fly with extreme flexibility and little effort (e.g., Barsalou, 1983). Indeed, Bowdle and Gentner (2005) were able to find traces of such a category learning process after only three training trials with a novel metaphor.

Fast and flexible learning also integrates more smoothly with the fact that switching between alternative mappings for a given conceptual domain is, at least sometimes, also fast and easy (e.g., McGlone & Harding, 1998; Gentner et al, 2002). The resulting picture of how the mind recruits and uses conceptual metaphors starts to look way more flexible than expected, even under the Metaphoric Structuring Views.

To summarize, the present review of research on conceptual metaphors of time has revealed a massive degree of cognitive flexibility. First, several alternative mappings are available to each individual within a single language and culture, as well as across different languages and cultures. The alternatives can vary in about every possible parameter: they can resort to different source domains to generate wholy inconsistent mappings; when they rely on the domain of space, they can map to all three spatial axes, to both poles within each axis, and taking each possible perspective. Second, there are clear effects of space on time, as well as effects of time on space, although the studies which have assessed both directionalities only report the former. Third, new conceptual metaphors can be acquired at an impressive speed, even in the face of highly practiced, life-long conceptual mappings for the same abstract domain.

Regarding the factors that mediate the manifestation of one or another conceptual mapping, reviewed studies point out the relevance of an attended supporting context (priming), of habitual exposure, use of linguistic expressions, and graphic cultural conventions.

This degree of flexibility poses a central problem to Conceptual Metaphor theory. Its psychological siblings, the Weak and Integrated Metaphoric Structuring Views, fare better in the face of the evidence by letting language to play a shaping role in the establishment of conceptual mappings and their directionality. Frequent language patterns lead to specific conceptual mapping habits, which may lead to the presence of alternative conceptual mappings both within a language and across languages. In the standard case in which the abstract domain is talked about in terms of the concrete domain more often than the converse, this view predicts asymmetric, stronger influences of the concrete domain on the abstract domain, which so far seems consistent with the evidence. However, under the assummed associative mechanism, the Metaphoric Structuring Views do not seem to be able to account for the easiness with which people areable to switch between alternative, simultaneously available mappings, nor for the speed at which old and highly practiced mappings can be replaced by new ones. Proposals from Bowdle & Gentner (2005) "career of metaphor" hypothesis could be fruitfully incorporated. Many questions remain to receive a definite answer, and among them, how is a metaphor selected out of the available alternatives in a given occasion figures prominently.

We now turn to evaluate whether available research on other abstract domains leads to consistent conclusions.

Cognitive flexibility in the domain of affective evaluation

The conceptual domain of emotional evaluation (positive-negative valence) also shows important within-individual flexibility, participating in several conceptual metaphors. A first one relates emotional evaluation to vertical space: positive evaluations are up and negative ones are down (which Lakoff & Johnson, 1980, called HAPPY IS UP, based on sentences like “I'm feeling down today”. We will name it POSITIVE IS UP because the metaphor applies not only to emotions, but to all positively evaluated concepts). The psychological reality of this vertical conceptual mapping is supported by several studies. Förster and Stepper (2000, exp. 1) reported that the learning of positive words was facilitated by adopting an upright posture, whereas negative words were facilitated by a back-rounded posture. This study suggests a possible body-based image schema motivating the mapping, which agrees with proposals by Lakoff and Johnson (1980). Consistently, Meier and Robinson (2004) observed that positive and negative words were evaluated faster when presented in the upper and lower parts of the screen, respectively, and Crawford, Margolies, Drake and Murphy (2006) showed that memory for location of positively valenced pictures is biased upwards relative to negative pictures (see also Weger, Meier, Robinson & Inhoff, 2007). Finally, Meier and Robinson (2006) reported that neurotic and depressive feelings were associated with faster detection of targets in lower spatial positions.

Evaluation also participates in two more space-conceptual mappings along the horizontal plane. The first one locates positive concepts close to self and negative concepts in far space. Lakoff and Johnson (1999) talked of a highly related metaphor: INTIMACY IS CLOSENESS (found in linguistic expressions such as “they are close friends” or “they feel far apart from each other”). Its image schematic foundation canprobably be found in the approach-avoidance tendencies generated by positive and negative stimuli. Cacciopo, Priester and Berntson (1993) found that ideographs are evaluated more positively if the participant is simultaneously performing an arm flexion (approach) rather than an arm extension (avoidance). It is also faster to respond to positive words by pulling a lever and to negative stimuli by pushing it (Chen & Bargh, 1999; see also Tops & de Jong, 2006). Evaluations activate approach-avoidance reactions to such a high degree that congruency effects have been observed using a lexical decision task (Wentura, Rothermund & Bak, 2000) and even when the task is just to detect the presence of a word on the screen (without any need to read it; Chen & Bargh, 1999). It has also been shown that approach-avoidance reactions are able to exacerbate preexisting valence differences (Centerbar & Clore, 2006).

The second mapping locates positive in right space and negative in left space (McManus, 2002). It is widely manifested in language (e.g., "sinister" comes from the latin word for "left") and its experiential basis is related to the greater fluency and easiness with which right-handed people interact with right space. Strong support for this assertion comes from Casasanto (in press), who found that lefties show the opposite association. It is also incorporated in a great many cultural conventions (e.g., burial patterns, arrangement of houses and churches, see McManus, 2002, for a review).

The evaluative positive-negative dimension therefore participates in three different space-conceptual mappings: POSITIVE IS UP, POSITIVE IS CLOSE and POSITIVE IS RIGHT, but little is known of the factors that guide the choice of one or another mapping in a particular situation. A study by Markman and Brendl (2005; see also van Dantzig, Zeelenberg & Pecher, 2009) adds to this flexibility by showing that the reference point (or deictic origin) on which the close-far horizontal space is centered can be freely moved onto an object different from self. Valenced words were evaluated by means of a pull-push joystick movement. The words were presented on the screen within a visual context which gave the impression of depth (a visual corridor). The participant’s name was presented at an intermediate distance in the corridor, and words could appear either below the name (“closer” to the participant) or above (“farther” than the name). The response requirement was always anchored on the name of the participant: to move the joystick towards or away from the name depending on word valence. In this situation, the well-known approach-avoidance congruity effect was replicated with respect to the position of the participant’s name on screen, and not with respect to the physical position of the participant. In a very clean manipulation, Seibt, Neumann, Nusinson and Strack (2008, Exp. 3) instructed their participants to either move their hand toward the word on the screen (approach) or away from it (avoidance), or to move the hand towards self (approach) or away from it (avoidance). The former instructions centered the deictic origin on the word, whereas the latter centered it on the participant. Word valence again interacted with approach-avoidance reactions as defined with respect to the current deictic origin.

Emotional evaluation has also been shown to participate in one additional conceptual metaphor based on a non-spatial domain: brightness, which maps positive with bright and negative with dark. As for the POSITIVE IS RIGHT mapping, the POSITIVE IS BRIGHT metaphor is not discussed by Lakoff and Johnson (1980, 1999), although it is easy to find linguistic traces of it (e.g., “dark ages”, “Darth Vader was attracted by the dark side of the Force”). Meier, Robinson and Clore (2004) showed that evaluative judgments to positive words are facilitated when presented in a bright versus dark font, and the converse occurs for negative words. In contrast to the highly automatic, nearly mandatory effects of evaluative meaning on approach-avoidance reactions discussed above, when the task was to judge the brightness of the font or to perform a lexical decision on the word, the effect disappeared. However, soon thereafter Meier, Robinson, Crawford and Alhvers (2007), using more ambiguous brightness stimuli, observed effects of a prior evaluation judgment on its perceived brightness.

Actually, coming back to the POSITIVE IS UP metaphor, the domain of emotional evaluation provides the clearest available case against both the Strict and the Lenient Directionality Hypothesis. The experiments 2 and 3 in Meier and Robinson (2004) study are very close to provide a fair comparison between effect sizes in the two directions of a cross-domain interaction: the effect of vertical space on affective evaluation and its converse. This contrast is made even more interesting by the fact that the domains of emotional evaluation and space show a sharp difference in the frequency of linguistic expressions talking about each one in terms of the other (i.e., positive-negative emotions are often talked about using spatial terms like “up” or “down”, whereas it is hardly possible to talk about space in terms of emotions, e.g., “it was a very sad cave” meaning a deep cave). Therefore, both versions of the Directionality Hypothesis make the same prediction: space should influence evaluation whereas evaluation should not affect space. In contrast, Meier and Robinson's (2004) second experiment presented positive and negative words centrally to be affectively judged, followed by the presentation of a stimulus (“p” or “q”) at either upper or lower locations to be recognized. Their third experiment presented a stimulus (“++++”) at either upper or lower positions to be located (participants responded vocally), followed by the central presentation of the same words to be evaluated. The former experiment found a clear priming effect of evaluation on space, whereas the latter found nothing.[1] We take these results to be clear evidence of the possibility of finding bidirectional cross-domain effects in spite of asymmetrical linguistic habits, although it could still be argued that the procedures were not exact reversals of each other and that the relative cleanliness of within-dimension processing was not explicitly assessed.

To summarize, reseach on the conceptual domain of affective evaluation provides clear examples of flexibility at the individual level, having been related to at least four alternative mappings: to upper and lower space in the vertical axis, to close and far regions from deictic origin, to left and right space in the horizontal axis, and to bright and dark visual stimuli. Moreover, by resorting to a different source domain, the fourth mapping is wholly inconsistent with the prior three. Reviewed evidence also suggests that the location of the deictic origin where the spatial axes are centered can be

1 It is surprising that the authors actually defended the opposite interpretation of their results, supporting the Strict Directionality Hypothesis. They state: “... one can make spatial discriminations without activating affective metaphors” (p. 244). However, their procedures are analogous to priming studies such as Boroditsky (2000) and others reviewed above, where processing spatial primes did affect subsequent processing of the temporal domain, even though spatial discriminations can be done without activating temporal metaphors. Instead, it was the processing of temporal primes which did not affect subsequent processing of spatial targets.

freely moved to other locations distinct from ego. Finally, it is possible to observe influences of the abstract domain on the concrete domain, which are stronger than in the opposite direction, supporting flexibility also in the directionality of the cross-domain mapping.

Regarding the mediating factors that affect flexible use of conceptual mappings, the relative automaticity of the mapping is important: positive and negative stimuli generate automatic approach-avoidance reactions, whereas their mapping to vertical space or brightness is less automatic.

Cognitive flexibility in the domain of social power

A conceptual metaphor which has received much attention by social psychologists maps power and status to the vertical dimension (Lakoff & Johnson, 1980, called it CONTROL IS UP; see Fiske, 1992, for a wider conceptual framework of social relations). In this mapping, powerful entities are located in upper space, powerless entities in lower space, as attested in many conventional linguistic expressions (i.e., “the decision came from above”). As for time, the mapping of control is continuous (Chiao, Bordeaux & Ambady, 2004), leading to a power gradient and rich inferential possibilities.

Schubert (2005) presented group labels such as “professor” and “student” to be judged as powerful or powerless. Words appeared either above or below the center of a computer screen, and responses were given by means of the up and down arrow keys. Both dimensions produced a congruency effect. Giessner and Schubert (2007) found consistent results manipulating the vertical extent of organization charts on judgments of the leaders' power. Schubert (2005) suggests that the image schematic basis of this mapping have to do both with bodily experiences (powerful people are bigger and taller, and feeling threatened or protected by a bigger person is probably a universal experience) and a complex of cultural conventions, from the arrangement of athletes on the podium to the location of bosses' offices in the upper floors of buildings. Schubert, Waldzus and Giessner (2009) reported data supporting that this metaphor should be actually understood as POWER IS BIG: in a power judgment task, they found congruency effects for words referring to powerful and powerless groups presented in big and small font sizes.

Schubert (2005) was very careful in dissociating these effects from those of the POSITIVE IS UP metaphor. Although the dimensions of power and evaluation are often positively correlated, he was able to find a set of powerful but negative words (e.g., “dictator”). Judgments of power on this set of words were facilitated when presented in the upper position of the screen. In contrast, when the judgment was about evaluation, performance was better when presented in the lower position. This is a clear example of cognitive flexibility in the selection of space-conceptual mappings depending on task requirements.

The study by Schubert et al (2009) also provides an example of quick learning of new conceptual mappings which are inconsistent with previously active and highly practiced mappings. As mentioned above, power judgments of words were automatically affected by font size. However, when the proportion of incongruent trials (powerful labels presented in small font, powerless labels in big font) was increased to two thirds and participants were informed about it, only 48 trials (38 incongruent) were enough to reverse the congruency effect in a subsequent test. Aspects of the results indicated that there had been a real learning process underlying the change and not just a strategic change. Furthermore, the outcome of this process was not only the elimination of a prior bias, but the creation of a new bias in the opposite direction. Only participants who were informed about the high proportion of incongruent trials showed the fast remapping, suggesting that voluntary attention to the relevant dimensions and mappings is an important factor involved.

Finally, there are also some hints of bidirectional influences between vertical space and/or physical size and social power, as several studies have shown that estimates of how tall a person is are biased by that person's power (Dannemaier & Thumin, 1964; Higham & Carment, 1992; Wilson, 1968).

To sum up, research on the conceptual metaphor of power has supported its mapping to vertical space and/or physical size; the possibility of reverting, in just a few training trials, prior life-long associations grounded in very basic bodily experiences as well as on a complex of cultural conventions; and the existence of bidirectional cross-domain influences. It has also revealed two important factors mediating the flexible deployment and learning of conceptual mappings: task requirements (such as being asked to judge affective evaluation vs. power) and voluntary attention to the relevant domains and mappings.

Cognitive flexibility in the domain of magnitude

Another vertical metaphor with some experimental support is MORE IS UP, which Lakoff and Johnson (1980) suggested from examples like “My income rose last year” and “If you are too hot, turn the heat down”. They also suggested that its image schematic basis came from experiences of piling up objects and observing the level to go up. In agreement with this suggestion, Josephs, Giesler and Silvera (1994) showed that pile size biased judgments of proofreading performance. Gattis and Holyoak (1996) found that graphs are easier to understand and reason about when the increase in quantity of a variable is mapped to an increase in slope.

Some studies in the domain of numerical cognition can also be interpreted as consistent with this metaphor. Numbers convey both magnitude information (4 is greater than 3) and ordinal information (4 comes after 3). It is common in many languages to refer to numbers using a vertical metaphor (“a high number”, “a low number”). Ito and Hatta (2004) used a parity judgment task (discriminate whether a number is odd or even), and showed that it is faster to press an upper key in a desktop keyboard to respond to relatively larger numbers, and to press a lower key to respond to smaller numbers. Schwarz and Keus (2004) found a similar result using saccadic eye movements instead of manual keypresses, thereby confirming the existence of a vertical analogue of the Space-Number Association of Response Codes (SNARC) effect first reported by Dehaene, Bossini and Giraux (1993; to be discussed below in detail).

The vertical SNARC studies cannot differentiate whether it is ordinal sequence or magnitude what is associated with the vertical spatial dimension. Neither they can tell us whether the relevant spatial dimension is the vertical axis or physical size (in which case the metaphor should be rephrased as MORE IS BIG). Another discovery in the domain of numerical cognition is more diagnostic: the effects of numerical magnitude on planning the size of a manual response. Lindemann, Abolafia, Girardi and Bekkering (2007) presented small (1, 2) and large numbers (8, 9) in a parity judgment task. Participants were asked to give their responses either by grasping a small rod with a precision grip with the index and middle fingers or by grasping a big rod using a power grip with the whole hand. Precision grips were initiated faster in response to small numbers and power grips to large numbers, even though magnitude was completely irrelevant to the task. Badets, Andres, Di Luca and Pesenti (2007) visually presented a vertical rod on a screen and asked their participants to estimate whether they could grasp it lengthways between their index and middle fingers. Each trial was preceded by a small (2) or large (8) number, or a neutral symbol ($) to be named aloud. The small number shifted the estimation distribution down, and the large number shifted it up, with the neutral symbol in between. These two studies provide another clear example of directional influences from the abstract to the concrete dimension of a conceptual metaphor, against the Strict Directionality Hypothesis, although they do not compare the relative sizes of both directions of the cross-domain effect.

A fair comparison of the sizes of the cross-dimensional effect in both directions has been provided in the context of a third research line in numerical cognition: the size congruity effect. In a typical experiment, the participant is asked to compare two numbers which differ in magnitude and physical size. The relation between the two dimensions defines a congruent condition (e.g., 2-8), an incongruent condition (2-8) and a neutral condition (2-8). The original report by Besner and Colheart (1979) instructed participants to decide which of the two numbers was of greater magnitude while ignoring their physical sizes. In accord with expectations from a MORE IS BIG metaphor, physical size interfered with magnitude judgments.

Furthermore, several studies have shown the converse influence of number magnitude on judgments of physical size (Henik & Tzelgov, 1982; see Pansky & Algom, 1999, for detailed references). Recent work has shown that the relative discriminability and salience of physical size and numerical magnitude determines which one will affect the processing of the other. Discriminability has to do with the "resolution" at which a conceptual dimension is sampled to select values for use in an experiment. Pansky and Algom (1999; see also Pansky & Algom, 2002, and Schwarz & Ischebeck, 2003) noted that prior research always used between seven and nine different numbers, whereas size was often manipulated in only two or three levels. The range and dispersion of values was thus greater for number than size, making number more discriminable. In several experiments, they manipulated systematically the relative discriminability of both dimensions, by equalling the number of levels while varying dispersion of values. Overall, the most discriminable dimension interfered with the processing of the less discriminable dimension. When both dimensions were equally discriminable, cross-dimensional interference was always symmetrical and its size was very small or null.

Regarding stimulus salience, Fitousi and Algom (2006) presented number and size information at different spatial locations, by using a fixed font for numerals and a varying length line appearing below the numeral. Stimulus salience was manipulated varying the size of the numeral and the line (i.e., to make the number dimension more salient, all numbers appeared in a greater font, and the lines varied around a smaller mean length). The more salient dimension always interfered with the less salient dimension.

The previous studies (Pansky & Algom, 1999; Fitousi & Algom, 2006) provide assessments of the relative size of both directions of the cross-domain effect between physical size and numerical magnitude under perfectly comparable conditions. Indeed, they only differ in the assignment of conceptual dimensions to being relevant (used to guide responding) or irrelevant. In these conditions, discriminability and salience switch the directionality of the cross-domain effect. These studies provide convincing evidence against the Strict Directionality Hypothesis. However, as it is (roughly) as common to talk about numbers in terms of size (e.g., "a small number") as to talk about size in terms of numbers (e.g., "that was a 500 squared meters house"), the Lenient Directionality Hypothesis predicts symmetrical cross-domain effects.

To wrap up, research on the domain of magnitude has shown a conceptual mapping between magnitude and vertical space or physical size. Studies on numerical magnitude have also shown parallel bidirectional cross-domain effects that stand against the Strict Directionality Hypothesis but can be accounted for by its Lenient version. Moreover, they have isolated several important factors that mediate the observed directionality: relative discriminability and stimulus salience.

Cognitive flexibility in the domain of linear order

Linear order or sequence order is a conceptual domain that has strong links with the domain of time. Actually, it can be said that most studies discussed in the section on time could also be included in this one. Our treatment of time focused on its two main correlates, event order and duration, often conflating them. We didn't try to make a systematic distinction between them because it is possible to argue that both can be reduced to a common kind of representation which segments the continuous flow of time in a sequence of discrete time units, therefore an ordered sequence of events (this assumption underlies most current models, both for extended sequences, e.g., Boroditsky, 2000, and short intervals, e.g., Ivry & Richardson, 2002).

However, there are other kinds of ordered sequences which have nothing to do with time, at least in principle. They are constituted by arbitrary sequences of elements, which may refer to an intrinsically ordered conceptual domain or not. For example, the letters of the alphabet are ordered only by convention. In contrast, numbers, days of the week and months of the year refer to an intrinsically ordered domain (magnitude or time). At one level, all of these sequence types require the representation of an arbitrary series of concepts defined by their position in the sequence and their order relations with the other elements of the sequence (e.g., Tuesday derives its meaning from its position within the sequence of weekdays). Some sequences, like the alphabet, weekdays or months, are short and overlearned. For other sequences, like the numbers, there are combinatorial mechanisms that, from a small ordered set, are able to generate an infinite extension of the sequence.

Given the similarities between time and these other ordered sequences, it comes as no surprise that they all display similar conceptual mappings onto space. We will review first literature about the mental representation of number sequences, and then proceed to the other types of ordered sequences (months, weekdays, alphabet letters...).

Numerical sequences

Two effects support that numbers are represented in some kind of analogical format (Dehaene, Dehaene-Lambertz & Cohen, 1998): the semantic distance effect (more difficult discrimination of numbers which are closer together than of numbers farther apart), and the number size effect (worse discrimination of numbers as their numerical size increases, a numerical counterpart of Weber’s law). Interestingly, this analogical number line extends in mental space from left to right, as it was the case for the mental time line. Dehaene et al (1993) found that people are faster to respond to small numbers with the left than the right hand, and to larger numbers with the right than the left hand, which they called the Space-Number Association of Response Codes (SNARC) effect. The name presupposes that the effect is an association between numbers and response codes, but studies using lateralized presentation of numbers (Keus & Schwarz, 2005; Zebian, 2005) and the priming studies discussed below support that it indexes a central analogical representation instead. In the years so far, a considerable literature on the SNARC effect has amassed (see Fias & Fischer, 2005, for a review), with several results which are directly relevant to the question of cognitive flexibility in conceptual metaphors.

Numerical order shows cross-cultural and cross-linguistic flexibility in its conceptual mappings. In direct correspondence with findings in the domain of time, the directionality of the number line seems to be affected by reading and writing direction, as the effect fades and even reverses in users of languages with right-to-left writing (Dehaene et al, 1993; Gevers & Lammertin, 2005; Shaky & Fischer, 2008; Shaki, Fischer & Petrusic, 2009; Zebian, 2005).

Wide flexibility within the individual is also attested. In a questionnaire study by Seron, Pesenti and Nöel (1992), 27 out of 194 people reported to have systematic images for numbers, which were aroused by merely seeing a number, and to use them when performing calculations. A variety of configurations were reported, including a majority of lines that could be vertical, horizontal, or having turns at key points (e.g., decades). Currently, there is experimental support in the general population for both horizontal (Dehaene et al, 1993) and vertical number lines (Ito & Hatta, 2004; Schwarz & Keus, 2004). As discussed in the prior section, though, the vertical mapping in these studies might be mediated by the association of number stimuli with another conceptual dimension, magnitude, and not with linear order. The study by Hung, Hung, Tzeng and Wu (2008) does not suffer from this potential confound. Using Chinese readers, they showed that the type of numerical notation (either Indo-Arabic or Chinese number characters) in which numbers were presented was able to induce a different spatial mapping: Indo-Arabic numbers generated a standard SNARC effect, indicating left-to-right mapping, whereas Chinese numbers generated a vertical SNARC suggesting a top-to-bottom directionality (larger numbers located in lower space). These results also strengthen the case for the direction of ortography and graphic conventions as causes of this spatial conceptual metaphor. Some studies have also supported a circular clock-face representation for numbers up to 10-12 (Bächtold, Baumüller & Bruger, 1998; Ristic, Wright & Kingstone, 2006; see discussion below). In some individuals numerical images are so automatic and systematic that they are categorized as a type of synaesthesia. Sagiv, Simner, Collins, Butterworth and Ward (2006) observed wide variation in preferred patterns, and were able to show SNARC effects tailored to the preferred pattern in each of five synaesthetes. Finally, a mapping of small numbers to close and large numbers to far peripersonal space have also been reported (Santens & Gevers, 2008).

Indo-Arabic numerals have also been able to facilitate subsequent spatial processing, showing a directional effect from the abstract to the concrete domain. Just looking to a centrally presented digit was enough to speed up processing of the corresponding spatial location (small numbers facilitated left space, large numbers facilitated right space) both in a detection task (Fischer, Castel, Dodd & Pratt, 2003), and an order decision task (say which of two lateralized stimuli has been presented first; Casarotti, Michielin, Zorzi and Umiltá, 2007). Other studies have shown the corresponding influence of a spatial prime on a numeric task (Keus & Schwarz, 2005; Stoianov, Kramer, Umiltá & Zorzi, 2008). Once again, no direct comparison of the sizes of both directions of the cross-domain effect is available.

It is interesting to note that, if only linguistic habits are taken in consideration, the Lenient Directionality Hypothesis would predict an asymmetrical influence between space and number, with number having stronger effects on space than the opposite. In another interesting parallel with left-right metaphors of time, it is common to say things like "the town was 20 Km away", but linguistic expressions like "2 is to the left of 6" or "when a right number is substracted from a left number" (meaning substracting a larger from a smaller number) are hardly ever attested. However, left-right space is conventionaly used to represent numerical order in charts and written language. If cultural conventions are included together with linguistic habits as a source of guidance for conceptual mappings, the Lenient Directionality Hypothesis probably predicts symmetrical effects between space and number.

Research on the SNARC effect has pointed out several mediating factors in the manifestation of space-number influences. Firstly, different number codes activate the mental number line to different extents. The association of numbers with space is strongest for Indo-Arabic numerals, even in implicit tasks such as parity judgment. Verbal numerals and other number codes produce smaller or non-significant effects instead (Dehaene et al, 1993; see also Razpurker-Apfeld & Koriat, 2006, for related evidence). This could be the result of practice, as when numbers are presented as an ordered sequence (e.g., on rulers, charts, and so on), they are most often written in Indo-Arabic format. A second one concerns the simultaneity of spatial and numerical processing. Stoianov et al (2008) reasoned that a spatial stimulus may be processed faster than a numerical stimulus. Correspondingly, they showed that a visual stimulus located at the left or right of fixation presented before a central number (e.g., "2") does not speed up a compatible response to the number (a left hand keypress). In contrast, if the spatial prime is presented a short time (59 ms) after the number, facilitation is observed. A third factor is voluntary choice of the spatial image for numbers. Bächtold et al (1998) reported that it is possible to change the association of number to space just by instructing participants. When they asked their participants to conceive of numbers “as on a ruler”, a normal left-right SNARC effect was found. However, when the instruction was to conceive of numbers “as on a clockface”, a reversed SNARC appeared, with faster left reactions to larger numbers and right reactions to smaller numbers (see Galfano, Rusconi & Umiltá, 2006, and Ristic et al, 2006, for analogous results).

SNARC studies have also provided evidence on a phenomenon that we will call *coherence interactions*, anticipating the interpretation that the theory to be presented in this paper will give to this family of effects. When people have to carry out two tasks simultaneously, both of which resource to an underlying spatial mental representation, people tend to align those representations to make them cohere, or to use a single common spatial representation. Notebaert, Gevers, Verguts and Fias (2006) presented digits centrally in either black or red font, randomly mixed. If the digit was black, participants performed a so-called inducer task: number comparison. One group was instructed to respond to digits smaller than five with the left hand and to larger digits with the right hand. A second group used the reversed mapping. The effect of the inducer task was assessed on a concurrent, diagnostic task: font judgment. If the digit was red, participants judged whether the digit was in normal font or in italics.

The first group (small numbers assigned to the left hand, large numbers to the right hand) showed a standard SNARC effect in the font judgment task. The second group (small numbers assigned to the right hand, large numbers to the left) showed a reversed effect in the diagnostic task. In other experiments, these authors found that the metaphorically incongruent number comparison task can induce reversals in purely spatial tasks (i.e., discriminating the color of a lateralized circle), and that incongruent spatial tasks can also induce reversals in number tasks. The important factor seems to be the overall coherence of the mappings simultaneously active during the experiment.

Are coherence interactions the automatic result of simultaneous activation of two different spatial mappings, or do they need some time to develop, and perhaps some practice? Another study supports the latter possibility. Lindemann, Abolafia, Pratt and Bekkering (2008) used a parity task with centrally presented digits. Each trial started with the presentation of a sequence of three numbers to be memorized, which could be in ascending (3-4-5), descending (5-4-3) or no order (5-3-4). At the end of each trial, memory of digit location within this sequence was tested. When each type of trial was presented in a separate block, a standard SNARC effect was found for ascending and disordered sequences, but it was eliminated in the descending condition. This change was observed in blocks of only 72 trials. When the three types of trials were randomly mixed, comparable SNARC effects obtained in all conditions. This study suggests that a coherent spatial representation between all concurrently active spatial mappings is not an automatic result. Instead, it looks like an strategic effect which needs some time and practice to develop, though not much. A bit longer practice would probably lead to a complete reversal of the SNARC effect, like in the Notebaert et al (2006) study using 384 trials-long blocks.

Other sequence types

Although numbers and other kinds of arbitrary sequences such as weekdays or months show important conceptual commonalities, the experimental evidence regarding the latter is not so clear-cut. Gevers, Reynvoet and Fias (2003) found SNARC-like effects for letters of the alphabet and months, Gevers, Reynvoet and Fias (2004) found them for weekdays, and Dodd, Van der Stigchel, Leghari, Fung and Kingstone (2008) found them for all three kinds of ordinal sequences. However, Dehaene et al (1993) failed to find a SNARC effect based on the alphabet, and Price and Mentzoni (2008) were unable to find it for representations of months.

Probably, the inconsistent results are related to the wide flexibility attested in these mappings within and across individuals, which is particularly strong for months sequences. Seymour (1980) report questionnaire and experimental evidence suggesting that months can be represented along horizontal and vertical lines as well as circularly. Some of his participants showed preferences for one particular spatial mapping, with all mappings being preferred by more or less equal numbers of people. In contrast, linear horizontal mappings were most frequently preferred for weekdays and the alphabet, and circular arrays were preferred for seasons of the year (see also Seron et al, 1992, for analogous results). As with numbers, there are also month-space-synaesthetes (Price & Mentzoni, 2008; Smilek, Callejas, Dixon & Merikle, 2007), a condition which often associates with number-space and colour synaesthesia (Sagiv et al, 2006). Month-space synaesthetes prefer circular patterns, but the specific location of months within them varies widely. In full agreement with data from number-space-synaesthesia, idiosyncratic spatial patterns produce corresponding congruency effects (Price & Mentzoni, 2008) and attentional biases (Smilek et al, 2007).

Sequences of different types also seem to differ in automaticity of access. Gevers et al (2003) reported that months interact with space even when month order is not task relevant (judging whether the month ended with ‘R’). In contrast, letters show a markedly reduced effect when participants make order irrelevant judgments (consonant-vowel classification). Dodd et al (2008) found that letters, months and weekdays induced spatial shifts of attention only when the processing of ordinal information was task relevant.

Overall, studies on linearly ordered sequences support the following conclusions. There are cross-linguistic and cross-cultural variations, coupled with wide within-individual variation. Clear bidirectional effects between the concrete and abstract domains are observed, against the Strict Directionality Hypothesis. Several factors mediating the manifestation of cross-domain influences have been isolated, namely, associative strength from number format, temporal overlap between the processing of both domains, voluntary choice of spatial shape and number-to-shape mapping, coherence interactions with other spatial mappings concurrently in use in the task at hand, and intrinsic differences in the automaticity of a given conceptual mapping.

Conceptual flexibility in the domain of pitch

Musical pitch is another dimension that is often talked about in spatial terms (a tone can be “high” or “low”), and this mapping affords the inferential possibilities characteristic of other continuous conceptual mappings. Other cultural conventions, like standard musical notation, also support this mapping in musically literate minds. There are also cultural conventions which support a left-to-right mapping of pitch onto space. For example, Lidji, Kolinsky, Lochy and Morais (2007) suggest that the piano keyboard acts as a cultural artifact for representing tone, having a wide influence in the minds of both musicians and non-musicians.

There is experimental evidence suggesting a spatial mental representation of pitch. Cohen, Hansel and Sylvester (1954), in a study on the Tau effect, found an effect of temporal intervals on pitch judgment. They presented three tones and asked participants to adjust the frequency of the middle tone such that it would be intermediate between the initial and final tones. The pitch distance between tones presented within a shorter time interval was perceived to be smaller, and therefore, the pitch of the intermediate tone was adjusted to be closer to the pitch of the tone presented after the larger interval. Cohen et al (1954) contended that these results show that Tau effects have nothing to do with space, being instead a general characteristic of all linearly ordered mental events. Jones and Huang (1982) counterargued that it is more correct to assume that pitch is underlyingly spatialized, and the auditory Tau effect is just a variant of the purely spatial Tau effect.

Pitch can map onto both vertical and horizontal spatial axes, indicating important within and between participants flexibility. Relevant studies also point out several mediating factors which agree with evidence from other conceptual metaphors discussed so far. Rusconi, Kwan, Giordano, Umiltá and Butterworth (2006) and Lidji et al (2007) found spatial compatibility effects for both axes in an explicit pitch judgment task (discrimination of high versus low tones by pressing up-down or left-right keys) in musically untrained participants. When an implicit task was used (discrimination of the instrument playing the tone), only trained musicians showed space-pitch compatibility effects in both axes, whereas untrained participants showed the effect only in the vertical axis, indicating that the vertical mapping is more intuitive and automatic than the horizontal (see also Repp & Knoblich, 2007). The whole pattern of results was clearer in Lidji et al (2007) than in Rusconi et al (2006), probably because the former used tones encompassing a wider range, thereby increasing the discriminability of the dimension of pitch.

The pattern of results suggests that pitch can be mapped quite automatically onto the vertical dimension. It can also be mapped onto the horizontal dimension if potentiated by practice or by task requirements (making pitch an explicit part of the task). Pitch discriminability also seems to mediate the manifestation of cross-domain effects, specially when the task does not require explicit processing of pitch.

Conclusions about cognitive flexibility in conceptual metaphors

In the first half of the paper we have undertaken a review of a wide landscape of research often coming from disparate traditions, and comprising a variety of (mainly primary) conceptual metaphors. It is surprising, therefore, how consistent the resulting picture is. Overall, conceptual metaphors are characterized by the existence of alternative mappings for the same abstract dimension which are available to the same individual or to individuals with different training histories, speaking different languages and/or being exposed to different cultural conventions. Moreover, cross-domain interactions do not always run exclusively in the direction from the concrete to the abstract domain, but very clear reversed influences are often found. There are even some hints (limited so far to the domain of affective evaluation) that it is possible to find cases of stronger influences from abstract to concrete in the face of more frequent linguistic patterns phrased the opposite way (using concrete terms to talk about abstract terms). Finally, this picture of wide, but lawful, flexibility is complemented by evidence showing a very fast and easy learning of new mappings in the place of lifelong, highly practiced mappings.

Several questions naturally follow: how are image schemas or simpler metaphors originally selected to structure new conceptual domains, out of the many potential candidates? How can new image schemas or metaphors be selected for application to a given conceptual domain which already has metaphoric conceptualisations in place? How do people choose which metaphor to activate in a given context? How do language and culture affect which metaphoric mappings are used?

A first step toward answering these questions requires the isolation of factors mediating the manifestation of a given mapping and the directionality of the cross-domain influence. The reviewed studies have exposed a complex set of them. Many of their effects seem to have an important degree of generality across different conceptual mappings. These factors include: 1) the intrinsic “strength” or automaticity of a given mapping and/or its practice level (it is unclear whether these two factors are separable); 2) the discriminability and salience of the stimuli used in the tasks; 3) the “strength” or automaticity with which the code conveying the concepts activate the conceptual dimension; 4) the presence of a priming context; 5) the degree of simultaneity in the processing of both dimensions; 6) the degree to which attention is either voluntarily or automatically drawn to the mapping or to either dimension; 7) the requirements on conceptualization imposed by the task; 8) the voluntary choice of imagistic conceptualization (which may recur to images more complex than linear or circular forms); 9) the coherence interactions in which the activated dimensions may enter; 10) the degree of conventionality of linguistic patterns used to talk about them; 11) their frequency; and 12) the existence of related cultural conventions.

The global picture is marked by cognitive flexibility to a much greater extent than it could be expected from Conceptual Metaphor Theory (Lakoff & Johnson, 1980, 1999). The degree of flexibility, especially when it comes to the directionality of the cross-domain effect, is such that we contend it cannot be accounted for by the two Metaphoric Structuring Views (Weak and Integrated) either (Boroditsky, 2000; Boroditsky & Casasanto, 2008; Casasanto, 2008), although a definitive test is still to come.

In order to see the deeper implications of the global picture, it is worthwhile to go back to the original motivation of the whole Solid Foundations View: the grounding of abstract concepts on the solid foundations provided by concrete concepts, in a recursive mapping leading down to the most basic universal image schemas and perceptuo-motor experiences. Conceptual Metaphor Theory, as formulated by Lakoff and Johnson (1980, 1999) constitutes the strongest version of such an enterprise. It does a good job at accounting for many linguistic patterns, but when its empirical base is widened to include behavioural experiments, it is faced with a problem for which it is not well equipped: how are several alternative mappings for a single domain learned, and how is one of them selected in a given occasion. Its psychological version, the Weak Metaphoric Structuring View (Boroditsky, 2000), held a better potential for providing such an account, as typically psychological factors such as priming and attention were allowed to enter the scene, though still the theory was far from providing a processing model. It also changed the ontogenetic theory, postulating a causal role for language experience at the expense of image schemas and perceptuo-motor experiences. The Integrated Metaphoric Structuring View (Casasanto & Boroditsky, 2008; Casasanto, 2008) came to acknowledge both sources of developmental influences on conceptual metaphors. Strict or Lenient Directionality remained as an essential part of the theory, and asymmetric cross-domain effects came in handy to serve as an empirical index for the progressive building of abstract over concrete domains. The Metaphoric Structuring Views could also be supplemented with a category formation mechanism (Bowdle & Gentner, 2005) instead of an associative learning mechanism to be able to account for quick learning of new mappings and their conventionalization into language.

Two points should be emphasized here. Firstly, linguistic experience (the frequency with which a conceptual domain is talked about in terms of another) and whatever learning mechanism is chosen do not by themselves assure that abstract domains will be structured by reference to more concrete domains. They can just as well serve to make analogies across two equally concrete or abstract concepts, or even support the "grounding" of concrete concepts onto abstract ones. Therefore, they fail in their goal of securing a solid foundation for abstract concepts onto experiential ground. Secondly, the inclusion by the Integrated Metaphoric Structuring View of experiential correlations as a main source of conceptual mappings which later come to be modified by the modulatory influence of language falls short of its explanatory goal of accounting for both universal and relativistic patterns. As long as language is granted the ability to choose from several available experiential grounds, making some of them salient and hiding others as if not experienced at all (or even establishing completely new, creative mappings), the role of language comes to be as causal as it is assumed by the Weak Metaphoric Structuring View (see also Rakova, 2002, for related arguments about the difficulty of reconciling universalism and relativism under a Solid Foundation View of concepts).

As a consequence, current Metaphoric Structuring Views need the asistance of another factor to make sure that these mechanisms work to place abstract concepts on solid concrete ground. This factor may be the fact that concrete concepts are more clearly delineated and structured than abstract concepts, and therefore there is an important tendency to use the former to help our thinking about the latter instead of the other way around. This difference predicts asymmetric cross-dimensional effects, which thus remain as a key index of the progressive building of abstract thought on concrete, solid foundations. The present review suggests that this prediction may not be held by the data, although the definitive test is still to be carried out.

Let us for a moment grant that available evidence supports unambiguously that bidirectionality in cross-domain interactions is the rule instead of the exception. What could now serve as the empirical index of how concrete or basic a conceptual dimension is? Put in other words, what empirical evidence could show that space, for example, is more concrete than time? Or, to give a more compelling example, that space is more concrete than pitch? Lacking an accepted criterium, we are left with a very different picture of how human conceptualization may work: one that would plainly accept that concepts at the first floor could be grounded by concepts at the roof (Figure 3).

Figure 3.- A Flexible Foundations View of abstract concepts (photograph by Kevin Pammet, all rights reserved, reproduced with permission).

The remaining part of this chapter constitutes an effort to provide a theory that takes cognitive flexibility seriously, bringing the processing dynamics that occur in the mental workplace to the forefront. Abstract thinking is to be severed from abstract long-term representations, and studied in its own terms. The central concern of the theory is to give an account of how conceptual domains are represented and processed in working memory in order to carry out successfully the kind of tasks reviewed above. Such an account is based on well-established psychological principles regarding spatial attention, spatial language, and working memory. With the help of some reasonable assumptions about long-term learning, the theory suggests a way in which working memory and long-term memory are connected, thereby also providing some hints about the long-term representation of conceptual metaphors. In what follows, we first describe the theory and some efforts explicitly aimed at testing it. In the final sections, we will explore the implications of the model for the manifestation of conceptual metaphors and the directionality of the cross-domain effect, the long-term learning of new conceptual mappings, and cross-linguistic and cross-cultural relativity issues. We will end by stepping back again and considering what expectations can be held from this view to solve the Symbol Grouding Problem.

A Flexible Foundations theory of metaphoric reasoning

A central aim of this second half of the paper is to present a psychological model of abstract reasoning using metaphoric projections. Many conceptual metaphors use space as a source domain to help us think about more abstract domains. Although the model can be generalized to a variety of source domains, it focuses on spatial conceptual metaphors in its current formulation. We first go through a short discussion of relevant principles in spatial cognition and attention. Then we introduce the main representational and processing assumptions about working memory. Next, we draw predictions and describe some empirical studies explicitly aimed at testing them.

Basic principles of spatial language and spatial attention

Spatial deixis, or pointing with words, requires selecting an object to work as an anchor or relatum (Levelt, 1989). In a simple type of deixis, no more than a relatum is needed (e.g., "bring that ball here" in which "here" refers to the proximity of the speaker). The relatum may be the speaker or it might be another object including the addressee ("put that ball close to you"). Garnham (1989) called this a *basic* relation. In more complicated forms of deixis, a coordinate system or reference frame is imposed on the relatum (see Levelt, 1989; Landau & Jackendoff, 1993; Levinson, 1996). When the relatum is the speaker (as in "put the ball to my left"), the reference frame is called a *deictic frame*. When the relatum is another object as in ("put the ball to the left of the chair"), the reference frame is called *intrinsic*. Levinson (1996) distinguishes a third type of reference frame: an *absolute* frame, which can be exemplified by the terms north, south, east, west. Finally, after setting a reference frame, spatial linguistic terms define a region of acceptability or spatial template (Landau & Jackendoff, 1993; Carlson-Radvansky & Logan, 1997) which is applied onto the frame (e.g., the English preposition "above" defines a region above but not in touch with an object, while "on" defines a region which is above and in touch with the object).

Logan (1995; Logan & Sadler, 1996) distinguished several processing operations which must be carried out when locating an object by means of a relatum and a reference frame. The reference frame must be created with the relatum at its origin, its axes must be aligned with intrinsic characteristics of the relatum, so that the up-down left-right and front-back dimensions are properly oriented, and its scale set. Spatial frames can also be moved and rotated in such a flexible way that Logan (1995) contended that they are part of the machinery of attention.

Much research suggests that in each moment there are several active spatial frames in competition (Carlson-Radvansky & Irwin, 1993, 1994; Carlson-Radvansky & Logan, 1997). Carlson-Radvansky and Irwin (1994) presented sentences using the term "above" and a picture of a relatum with an intrinsic vertical axis and a located object. Sometimes the object was upright, such that viewer-centered, environment-centered and object-centered frames were aligned. In other occasions the object was rotated, such that the object-centered frame was misaligned with the other two. In a final experiment, some groups carried out the task with the heads tilted, thus dissociating the viewer-centered frame from the environment-centered frame. In all cases, sentence to picture matching times gave signs of being affected simultaneously by competition between multiple reference frames, and not only by the one guiding the yes/no response.

Carlson-Radvansky and Irwin (1994) also found that co-activated frames vary in their salience: the environment-centered frame exerted a stronger influence than the object-centered frame, whereas the viewer-centered frame did not have a significant effect. Frame salience and competition were affected by instructions to a certain extent, but it was not posible to override them completely. The salience of spatial reference frames can also be affected by factors such as the presence of salient cues (Li & Gleitman, 2002; Levinson, Kita, Haun & Rasch, 2002) or patterns of alignment and mis-alignment between frames (e.g., Shelton & McNamara, 2001). The dimensions within a reference frame also vary in salience: the vertical dimension is more salient than front-back and left-right (Rock, 1973). Some theorists suggest that this is because verticality is determined by gravity, upright posture, body symmetry and other very salient and consistent signals (Levelt, 1989). This is not the case with the horizontal left-right and front-back axes. Correspondingly, Franklin and Tversky (1990; see also Logan, 1995) found that it was faster to find objects along the vertical dimension than along the two horizontal dimensions. Finally, Carlson and Van Deman (2008) showed that it is possible to prime separate frame components, suggesting that it is possible to access selectively a single axis, with or without specification of its poles, or a whole frame. More salient frames tend to be activated as a whole, whereas less salient frames can be partially activated.

Because of this flexibility, spatial representations and mechanisms seem very well endowed to explain many of the types of interactions and some of the intervening factors that were described in our prior review of cross-domain conceptual mappings. The mental workspace may contain many simultaneous spatial frames of reference which can be set up and moved with an impressive degree of flexibility, which affect spatial processing depending on perspective or deictic origin, and with intrinsic variations in automaticity or “strength”. The following section builds on these conclusions to present a view of working memory which can provide a coherent account of prior evidence regarding conceptual metaphor processing, as well as make several new predictions.

Mental Working Spaces, Activation, and Coherence Mechanisms

In this section, we sketch a theoretical framework which makes use of attentional and linguistic mechanisms working on embodied representations of abstract meaning in a mental workplace. Most of its postulates are not new. To the contrary, there is wide agreement on many of them. The framework is thus offered as an integration of theoretical ideas that so far have not been put together in a coherent way, and as a heuristic tool to guide future research and theorizing about conceptual metaphors.

It should be emphasized at the outset that the view of working memory to be described here has very little in common with the view advocated by Alan Baddeley and coworkers (see Baddeley, 2007, for a recent review). Baddeley's Working Memory is a system composed of unimodal, separate and distinct subsystems. In our view, working memory is instead a multimodal, highly integrated system which combines the outputs of perception, language and memory into a complex representation which is able to guide situated action.

A first postulate of the model is a mental workspace endowed with both structure and content. Structure is provided by both structural dimensions and image schemas, constituting the scaffolding on which concrete contents are placed (Johnson-Laird, 1983; Fauconnier, 1985; Jackendoff, 2002; Talmy, 2000). All kinds of elements have activation levels which determine their inclusion in the mental space or model and their ability to interact with other elements (we use the terms “mental space” and “mental model” as synonyms).

Following Johnson-Laird (1983), we assume that there is a basic mental space which is directly linked to our perceptual experiences. Its reference frames are constructed with the three perpendicular dimensions of physical space. It also contains representations of objects located in space and the observer's viewpoint or deictic origin. Spatial location is coded by means of reference frames, which define positions with respect to reference points. Image schemas such as CONTAINMENT or SUPPORT can also be added, if activated, to provide further structure. Individual contents (physical objects) are located within the structure, therefore holding varying types of relations between them.

The perceptual space holds a representation which is analogous to the outer reality. Representations of objects and reference frames in this space can be located, moved, rotated and contemplated from another viewpoint at will, thereby allowing many visuospatial inferences. The perceptual space is probably constructed in very similar ways by many animal species, and its basic design characteristics are in all likelihood universal in humans.

In line with other theorists, we assume that the mind creates and uses a variety of mental spaces for different purposes, including navigating, reasoning, and using language (Johnson-Laird, 1983; Fauconnier, 1985; Fauconnier & Turner, 2002; Jackendoff, 2002). Following Johnson-Laird's analysis (1983), the evolution of language in humans brought up the possibility of labelling the contents within the mental space. The linguistic labels then became the key factor for determining element identity, overriding physical similarity and other perceptually based cues. A black dot on a white field may be a person, a fly, a planet or whatever it is labelled to be. We suggest that the capacity of holding and manipulating abstract thoughts through spatial conceptual metaphors depends crucially on labelling representations of physical objects with abstract labels and locating those "abstract" objects on the physical dimensions of space, which in turn can also hold abstract labels such as time or emotional evaluation.

Linguistic labelling is able to support the distinction between types and tokens, i.e., some object in the model may be labelled either as representing the category CAR or just a specific car (see Jackendoff, 1983, 2002, for discussion of the distinction between types and tokens and the intricacies of their representation in short and long term memory). However, because the mental workplace still retains the design of the perceptual model, the labelled object in the mental space must be a concrete object taking a concrete shape and located in a particular point of the structural scaffolding. It holds concrete relations with other objects, even if those relations are within dimensions with abstract labels. When we think of "cars" in general, we still represent them by means of particular instances in the mental space. This is in agreement with the wide literature on language comprehension and embodiment within the Simulation tradition (e.g., Stanfield & Zwaan, 2001; Zwaan, Stanfield & Yaxley, 2002). It also accounts for the abundance of metaphoric gesture accompanying speech, as in the psychology professor example that opened this chapter (McNeill, 1992). Our contention is that the grounding of meaning arises necessarily from the fact that the design characteristics of the mental workplace are the same that developed to represent the perceptual world. In other words, the mental space used for abstract thought is essentially the same as the one that is used for perceiving and acting on the environment.

We suggest that the acquisition of language did not lead to any substantial change in the way mental spaces are built: the reference frames hold a maximum of three perpendicular structural axes, they contain representations of concrete objects and they are structured by the same kind of image schemas. The objects, dimensions and schemas labelled as abstract concepts gain new characteristics from their abstract meaning, keeping at the same time many of their perceptually based properties. As a result, they can be used to support abstract reasoning. For example, after a vertical axis is labelled as the social dimension of power, objects representing people can be located at different heights of this dimension. Apart from allowing perceptual judgments of "social distance", it also supports judgments of, say, who should show respect to whom with only a glimpse at the mental space.

The social power example shows a counter-intuitive property of mental spaces. Even though the reference frames are constrained to have a maximum of three perpendicular axes because of their basic perceptual nature, there may be more than one active frame with different labels. Imagine a scene in which a soldier talks to his captain. While both persons are located (more or less) at the same height in the physical vertical dimension, they are located at different heights of the social power vertical dimension. Contents may be located simultaneously at different points of the "primary" physical vertical dimension and the "secondary" social hierarchy vertical dimension. When in a model there are both primary and secondary dimensions, primary dimensions have priority over secondary in determining how the model is seen from the perspective of the observer (although secondary dimensions may induce subtle biases). When the model only requires the inclusion of secondary dimensions, they may determine how it physically looks like. If asked to think of ranks in the army, participants probably set up a mental model with rank-labelled objects arranged along a vertical axis labelled rank.

A central property of the contents of the mental working space at any given time is their degree of activation. When a mental representation gathers enough activation, it is on the focus of attention. This notion of focus is wider than that used in space-based theories of visual attention (e.g., Posner, 1980), being closer to the notion of discourse focus (Levelt, 1989). Representations which are above a certain threshold, and therefore in focus, are processed in a more efficient way. They are also able to exert effects which are forbidden to out-of-focus (or below-threshold) representations, such as guiding further processing, directing attentional mechanisms, or interacting with other relevant representations for establishing global coherence (to be discussed below). They can also be subjected to voluntarily controlled goal-directed manipulation. Variations in activation affect the degree to which in-focus representations participate in these kinds of above-threshold interactions. Representations activated below threshold can be said not to be part of the mental space, although they can participate in a variety of below-threshold interactions (MacKay, 1987).

Many different factors can affect the degree of activation of a representation. Some are exogenous factors, such as the greater salience of the vertical dimension of space (Rock, 1973; Franklin & Tversky, 1990). Another example is the intrinsic ability of symbolic signals such as linguistic spatial terms ("above", "below", "left", "right"), arrows (Hommel, Pratt, Colzato & Godijn, 2001; Mayer & Kosson, 2004), eye gaze and body parts (Ansorge, 2003; Friesen & Kingston, 1998, 2003) to capture and direct attention to particular spatial locations even without predictive power. Concepts can be called up by stimuli in different formats, which may have different intrinsic capacity to activate their representations (e.g., Arabic numerals versus number words, Dehaene et al, 1993). This intrinsic capacity is strongly linked to extended practice and automaticity of processing (for modern views on automaticity, see Anderson, 1982; Logan, 1988). When the input is linguistic, the devices by which language controls attention deployment to certain representations over others become crucial (Talmy, 2000, 2003; Taube-Schiff & Segalowitz, 2005). Stimulus characteristics such as abrupt onset, parafoveal location, unpredictable movement and so on, which are able to automatically capture attention toward a stimulus (Ruz & Lupiáñez, 2002), and explicit task requirements also increase the activation of its associated representation. Finally, endogenously controlled factors and voluntary will (Posner, 1980; Jonides, 1981; Jonides & Yantis, 1988) may also boost the level of activation of particular representations. These different sources of activation enter into a weighted sum which renders the total activation of a given element in the mental working space. All these attentional factors can also affect the choice of deictic origin, i.e., the point from which the subject views the mental model.

A final component of the theory is a mechanism aimed at reducing the total number of degrees of freedom present in the mental space. Somehow, this coherence mechanism tries to satisfy simultaneously the many constraints that the contents of the mental space pose to each other, making the global representation stable and coherent (see Thagard, 2000, for a general treatment of coherence). Many inferences are automatically drawn as part of the workings of this mechanism: the representations may be changed, new contents brought up and others deleted, and structural dimensions may be conflated. The resulting representation is maximally informative and useful for the task at hand with the minimum storage cost and processing load. This mechanism is similar in spirit to the rules of good shape proposed by Gestalt theorists (Kohler, 1929), to the idea of equilibrium in integration networks of mental spaces (Fauconnier & Turner, 2002), and to the constraints of Optimality Theory (see Archangeli & Lagendoen, 1997, for a review). It is also consistent with the rules that guide the mesh of affordances in Glenberg's theory (Glenberg, 1997; Glenberg & Robertson, 2000) or the creation of simulations in Barsalou (1999, 2003; Barsalou et al, 2003), as well as with the relevance-creating mechanisms of Relevance Theory (Sperber & Wilson, 1986). It may be argued that all the studies which find congruency effects between task dimensions provide supporting evidence for a coherence mechanism of some kind.

An important point to note is that setting up and maintaining a mental model is something that takes effort. The amount of effort is determined by the complexity of the model in ways that relate to the number of elements which are not consistent with other elements in the model (Johnson-Laird, 1983). This supports the expectation that people will always try to set up only the minimally complex mental model which allows dealing satisfactorily with the situation at hand. Such principle of rationality pervades both strategic planning of one's behaviour and interpretation of the behaviour of others (Grice, 1975; Shank & Abelson, 1977). In the current context, it is a necessary ingredient to be able to extract predictions from the theory. We postulate that searching for coherence in the model is effortful too, so whether it is worthwhile to pursue a coherent model will be strategically chosen depending on the situation. Nevertheless, coherence reduces global complexity and mental effort, which makes it a useful strategy in many situations. People will always try to arrive at a model that maximizes simplicity and coherence and minimizes effort, in the context of current goals and circumstances.

A final central assumption of the present theory is that the coherence mechanism exists only in working memory. It works against having inconsistent mappings simultaneously active within a mental model. However, mental models using inconsistent mappings can be built on different occasions. If each successful use of a model is committed to long term memory, and its internal mappings are strengthened through repeated use, a variety of inconsistent mappings for the same conceptual dimension will reside in long term memory side by side, without conflict. They are only pressed to be consistent when simultaneously activated and entered into a single mental model in working memory.

To summarize, the present theory asserts that the proximal determinant of behaviour is working memory. Working memory is a multimodal, integrated, optimally coherent and detailed mental space, populated by labelled elements (objects, structural dimensions and image schemas), which is aimed at maximazing goal attainment with a minimum mental effort. The ontology of the mental workspace, the selected structural and content units, their labelling and concrete shapes, their positioning into the structure, their relative degree of activation, and finally, the kind of coherence interactions established among all of these elements, are the chief factors which determine which behaviour will be observed in a given experimental task.

Testing the theory

A central prediction of the present framework is that the key aspect that governs the manifestation of conceptual metaphors in behaviour relates to the simultaneous inclusion of both the abstract and concrete dimensions within the current working mental model, such that both sets of dimensions are able to constraint each other. The theory predicts that the more salient dimension will be able to interfere to a greater extent with the less salient dimension, and therefore they will interact when the coherence mechanism is applied to the model. This mechanism reorganizes the contents of the model to produce a maximally coherent overall description of the situation, which in turn provides guidance for coping with that situation with a minimal mental effort. If the response is based on the less salient dimension, (in)congruency effects are expected. More succinctly, manipulating the degree of activation of both the concrete and abstract dimensions will affect their ability to interact, and therefore the finding of conceptual metaphoric effects on behaviour. We now turn to research aimed explicitly at testing this suggestion. We will describe two so far unpublished experiments, and discuss in detail other relevant work from our lab (Torralbo, Santiago & Lupiáñez, 2006).

Other important predictions follow from the distinction between working memory and long term memory, the long term storage of working memory models with practice and repetition, and the suggestion that only working memory struggles to be internally coherent, whereas long term memory can be populated with contradictory representations without conflict. The implications of these assumptions will be followed up in the final sections of this chapter.

Experiments on the vertical axis and voluntary attention

Santiago, Román, Ouellet and Castro (in preparation) focused on affective evaluation using words relevant to the HAPPY IS UP conceptual metaphor. Participants read Spanish emotion words, such as “feliz” (happy) and “triste” (sad), and were asked to judge whether the word referred to a positive or negative emotion. A silhouette of a human face looking rightwards was presented centered on the screen, and words were presented either above or below the face (see Figure 4).

Figure 4.- Stimuli used in Santiago et al (in preparation).

The procedure is analogous to that used by Meier and Robinson (2004, exp. 1), with a single difference: word location was not cued just before word presentation. Therefore, it is possible that our experiment does not activate the vertical spatial dimension to the same extent. Consistent with this suggestion, both space and affective evaluation affected response latency (with faster responding to upper than lower words, and to positive than negative words), but there were no traces of an interaction between them.

Experiment 2 tried to increase the amount of attention voluntarily paid to the spatial dimension by changing the instructions given to participants. A paragraph was added to the instructions explaining that there would be a secondary task to be carried out simultaneously: a greater number of words would be presented at one of the two screen positions; at the end of the session, they should report at which position there were more words. The task was presented as a difficult task because the number of words at each position would be only slightly different. Actually, as in Experiment 1, there were exactly 50% words at each site. If the reason why no spatial-conceptual interactions were found in the first experiment has to do with the processing of the literal spatial up-down dimension, this manipulation should make participants to pay attention to the position where words are presented, thereby increasing the activation of this dimension. The dimension of space should then be included in the model, entering into coherence interactions with the other active conceptual dimension of affective evaluation. Note that the conceptual processing side of the task (judging emotional valence) remains untouched by this manipulation.

During debriefing, many participants in Experiment 2 reported that they started the session trying to keep a count of words at one of the two positions, but many of them acknowledged that after a while they felt that the difference was too small and gave up the secondary task during the experiment. It is therefore possible that participants followed the instructions at the beginning of the experiment, but then changed to perform in a fashion which would be analogous to Experiment 1. As the experiment consisted of two identical blocks of trials, we looked at them independently.

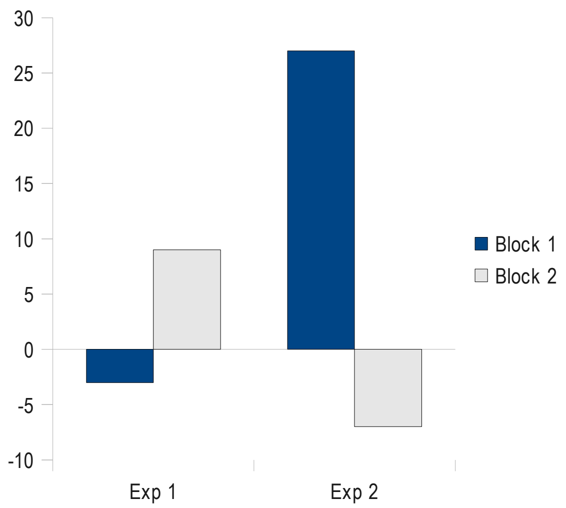

Figure 5.- Size of the congruency effect (incongruent minus congruent conditions) in each half of Experiments 1 and 2 of Santiago et al (in preparation).

As suspected, position and meaning interacted only in the first block of the experiment, whereas the second block showed no traces of such interaction. The size of the spatial-conceptual congruency effect (obtained by substracting the congruent conditions positive-up and negative-down from the incongruent conditions positive-down negative-up) amounted to 27 ms in the first block and shrinked to -7 ms in the second block (see Figure 5).

Therefore, the voluntary allocation of attention to the vertical axis produced detectable effects of the spatial conceptual metaphor underlying the processing of emotional meanings. This study provides evidence for the hypothesis that concrete dimensions need to be salient enough to be able to interact with concurrently processed abstract dimensions. An interesting point to note is that this study differs from others which also show effects of voluntary strategies (e.g., Bachtöld et al, 1998; Galfano, Rusconi & Umiltá, 2006; see review above) in that we did not instruct our participants where to locate the positive and negative poles of the evaluative dimension, but just to attend to the whole dimension. This suggests that attention is only a mediating factor, and not the only cause of the observed pattern.

Experiments on the horizontal axes and automatic attention

Another series of experiments from our lab (Torralbo, Santiago & Lupiáñez, 2006) used a similar logic but manipulated attention through automatic means. This study focused on the temporal metaphor TIME IS MOTION. As reviewed above, there is experimental evidence supporting two variations of this metaphor in Western left-to-right writing cultures: one that maps future onto front space and past onto back space (e.g., Boroditsky, 2000) and another that maps past onto left space and future onto right space (Santiago et al, 2007, among others, see above). Spanish words (tensed verbs and temporal adverbs) were presented on a screen and participants gave a speeded judgment of whether the word referred to the past or to the future. The crucial aspect of the procedure was that the spatial arrangement of objects on the screen allowed the simultaneous application of both the back-front and left-right time metaphors. A silhouette of a human profile was presented centered on the screen, facing either rightwards or leftwards. Words were presented within a balloon either to the right or to the left of the silhouette (see Figure 6). Participants were instructed to judge whether the "person" was thinking of her past or her future. In this situation, if the deictic origin is placed on the silhouette, past and future words are presented in its back and front space. If the deictic origin is placed on the participant, past and future words are presented in left and right space. Because the silhouette changes its direction of sight randomly from trial to trial, and because all words are presented at both the left and right locations, both frames (the back-front and left-right axes) are orthogonal. Note that both axes are also equally irrelevant to the conceptual task (judging the words' temporal reference).

The first experiment used a vocal response: people pronounced "pasado" (past) or "futuro" (future). In this situation, we predicted that the left-right spatial dimension would not be included in the model, because it has a low intrinsic salience (Franklin & Tversky, 1990), it is not being voluntarily focused, and nothing in the task requires it. In contrast, the back-front dimension would enjoy a high level of activation, because both faces and random changes automatically attract attention (Friesen & Kingstone, 2003). Out of the two spatial conceptual mappings available for time in long term memory, the search for a maximally consistent mental model would most likely select the back-past front-future metaphor in this situation. Therefore, the temporal meaning of words should interact with the position occupied by the word in the back-front axis of the silhouette: future words should be responded to faster when presented in front of the face and past words when presented behind the face, independently of whether these positions were to the left or to the right of the screen.

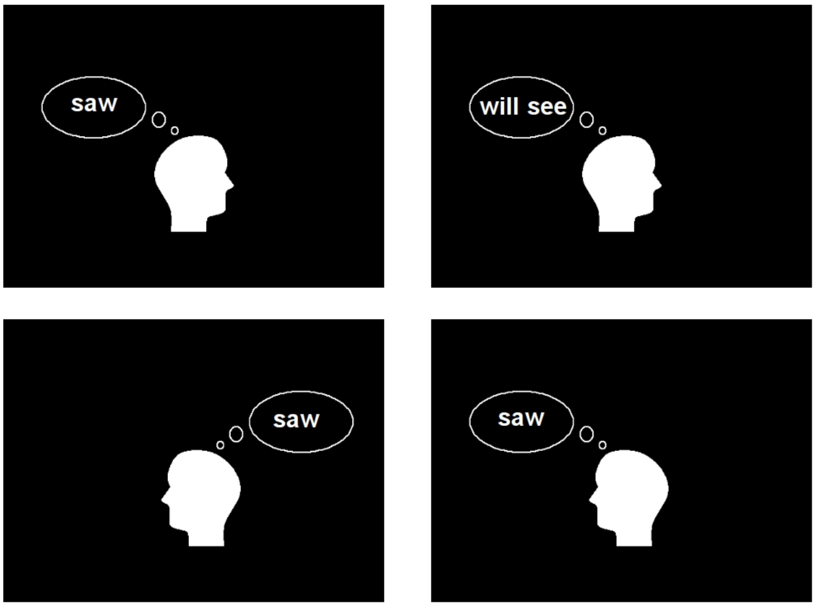

Figure 6.- Sample of stimuli from Torralbo et al (2006). All eight combinations of left-right word presentation and left-right face direction were used.

The results supported this prediction: words presented at metaphorically congruent positions in the front-back spatial frame were 15 ms faster than words presented in incongruent positions, a statistically significant result. In contrast, words presented at congruent positions in the participant-centered left-right spatial frame were a non-significant 2 ms slower than words at incongruent positions.

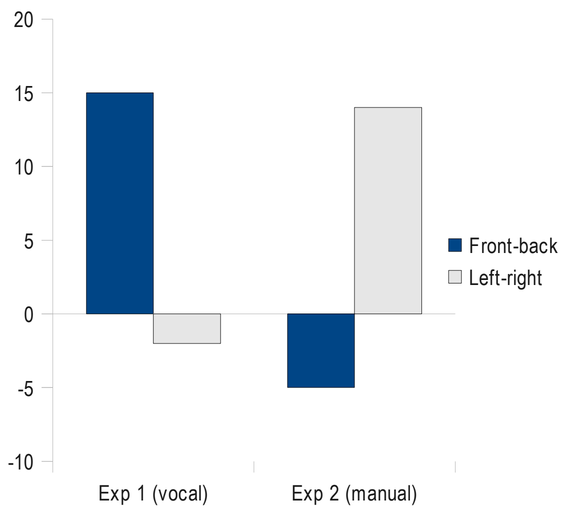

Figure 7.- Size of the congruity effect (incongruent minus congruent conditions) for each reference frame (face intrinsic front-back or observer-relative left-right) in Experiments 1 (vocal response) and 2 (manual response) of Torralbo et al (2006).

In a second experiment, the salience of the left-right frame was increased through exogenous-automatic means by changing to manual responding using left and right keys. This task requirement should force the inclusion of the left-right spatial dimension into the mental model of the task. We expected that the high activation of this spatial frame would bias the results of the search-for-coherence mechanism in two ways: first, the conceptual mapping of time onto the left-right dimension would be selected; and second, the deictic origin would be moved from the face in the screen onto the participant. In this situation, it was predicted that the processing of word meanings would be speeded up only in positions congruent with the left-right conceptual metaphor, and not with the back-front mapping.

The results again supported the expectations: past words presented on the left and future words presented on the right were now 14 ms faster than the same words presented in the opposite positions. Moreover, the back-front axis lost all trace of its former effect, which came down to a non-significant -5 ms (see Figure 7).

Torralbo et al (2006) results provide strong support for several claims of the present theoretical framework. First of all, several inconsistent conceptual metaphors can coexist in long term memory and be selected and used in different occasions. Note that we did not instruct participants about where to locate the poles of the time dimension, whichagain supports that the choice is based on stored mappings. Second, only one of those inconsistent mappings can be used on a given occasion (unless they are somehow blended, Fauconnier & Turner, 2002). Third, there is a great deal of cognitive flexibility in the selection of conceptual metaphors, as much as it is attested in non-metaphorical spatial cognition. This points to the intervention of basic attentional mechanisms which treat metaphorical dimensions in a similar way to how they treat concrete, perceptually-based dimensions. Fourth, the search for a globally coherent mental model is an important force molding the final shape of the mental model. Finally, these results, taken together with the experiments by Santiago et al (in preparation) support the idea that both endogenous-controlled and exogenous-automatic attentional factors affect the degree of activation of the elements of the mental model and the choice of deictic perspective, thereby modulating its interactions.

Implications and extensions

The Manifestation of Conceptual Metaphors in Behaviour

A central prediction of the present theory is that the manifestation of spatial conceptual metaphors depends on the simultaneous presence in working memory of both spatial and abstract concepts, their relative activation and their coherence interactions. This kind of interactions explain why it is possible to observe the manifestation of a spatial-conceptual mapping when the degree of activation of the associated (irrelevant) spatial dimension is increased in the experiments just described. The theory also allows a unified explanation of the studies reviewed in the first part of this paper.

The present theoretical framework readily accounts for the availability of several alternative, and often inconsistent, mappings for a given conceptual domain in the long term memory of a single individual, as well as across individuals, languages and cultures: people can conceptualize an abstract domain in wholly different ways in different occasions and learn them all. They are only constrained not to use them at the same time within a single mental model. The theory also predicts that bidirectional interactions across domains will be the rule and not the exception, and poses clear conditions: whenever the effect of the more active dimension is assessed on the less active dimension while both of them are simultaneously active in a mental model. Finally, the theory supports a very fast use of new mappings in the face of life-long habits: although practiced habits will tend to be used all other factors being equal, people have an enormous control on their conceptualizations of situations in working memory. For example, insight problem solving is based on the sudden set up of a new, and successful, mental model for a problem, often after giving signs of trying many alternative configurations. As soon as a new way of conceiving a problem proves useful, it tends to be learned immediately and used in subsequent occasions (see, e.g., Dunbar, 1998).

The theory is also able to account for the influence of all mediating factors isolated along our review of relevant literature, and suggests that they can be grouped into three main categories:

a) Factors affecting the strength with which activating a given abstract concept primes a particular metaphoric mapping (i.e., the strength of the habit of thinking about an abstract domain in terms of another in a particular configuration): practice of the mapping, degree of conventionality and frequency of consistent linguistic patterns and cultural conventions. All three factors can be actually subsumed under the first, as habitual language is just a source of pressure to practice a mapping. Other sources are possible. For example, mapping affective valence to the close-far dimension has a higher degree of automaticity than alternative mappings probably because it supports approach-avoidance reactions, which are relevant and useful in a greater proportion of valenced situations.

b) Factors affecting the strength with which aspects of the task activate an underlying conceptual dimension: this includes variations in the efficacy of different codes (e.g., number concepts being activated more strongly from Indo-Arabic numerals than from number words), perceptual salience, perceptual discriminability, priming context, task requirements, and degree of attention voluntarily paid to or automatically attracted by the stimulus. Voluntary attention is in turn mediated by factors like instructions, goals, motivation, etc., and exogenous attention is affected by factors like abrupt onset, parafoveal location, predictability and so on.

c) Factors affecting coherence interactions between dimensions within a mental model: relative activation (related to a and b), simultaneity of processing, availability of enough time and motivation to adopt stricter coherence strategies.

d) Factors affecting the choice of perspective or deictic origin from which the mental model is considered: this set includes many of the factors mentioned in a-c, being specially relevant both exogenous and voluntary attentional factors.

The Acquisition of Conceptual Metaphors

The present theory suggests that the most important factor for the establishment of new conceptual metaphoric associations between two semantic dimensions is their being simultaneously included in an active mental model (similar claims have been proposed from research on implicit learning and automaticity: Jiang & Chun, 2001; Jiménez & Méndez, 1999). By coexisting in working memory, a spatial and a conceptual representation become associated. Once this space-conceptual association is stored, there will be a tendency towards using it again in the future. The more frequent the association, the greater this trend.

Nothing precludes storing of conflicting space-conceptual mappings in semantic memory, as the result of different learning experiences. Only individual mental spaces are constrained to be globally coherent. Once a particular mapping is stored, it may be activated and it can then place constraints on the final shape of mental models in which that concept intervenes. When there are conflicting mappings for a given concept, the use of one or the other in the model is affected by the factors influencing degree of activation, and by coherence interactions with other elements in the model.

Let's follow in detail the acquisition process of a conceptual metaphor using the source domain of space. People often use spatial strategies to solve problems. For example, if participants are asked to press a left button when a red square is presented and a right button when the square is green, probably many of them will generate a mental model in which the label RED is assigned to a concrete object located to the left and the label GREEN to an object on the right in the left-right spatial dimension. The mentally represented object might be a written word, a coloured patch or anything that the person finds useful. The important point is that, being labelled as RED, it will be used to stand for the concept of "redness". The repeated use of this spatial-conceptual mapping would lead to the storage of a permanent association between RED and left space and GREEN and right space in long term semantic memory. Further practice will strengthen the association and make its use more likely in new situations.

De Hower (2004) actually carried out a very similar manipulation. He trained participants to say "cale" to a leftward arrow or the word "left" and to say "cole" to a rightward arrow or the word "right". In a subsequent block, participants were to say "cale" to a blue square and "cole" to a green square. A clear Simon effect emerged: blue squares were responded to faster when presented on the left side, and green squares were faster on the right side. The effect was thus mediated by the prior association of "cale" to left space and "cole" to right space (see also Pellicano, Vu, Proctor, Nicoletti & Umiltà, 2008).

The general claim is that whatever dimensions, schemas and contents are simultaneously active in working memory, they will enter into coherence interactions and become an optimally coherent mental model. The model will be later committed to long term memory. This mechanism provides a way for acquiring initial content for an abstract continuous dimension, such as TIME and EVALUATION, through the kind of experiential correlations that are assumed to underly many conceptual metaphors. If attention is simultaneously paid to forward movement of the person in the front-back dimension and to the impression of duration, both dimensions may be included into a coherent model, which will export a lot of spatial structure to the domain of time. Storing many similar models will entrench this spatio-temporal conceptual mapping in semantic memory.

The concrete domain may be included in the model based on actual perceptuomotor input, as in the example above, or by linguistic input, both through its literal content, through presuppositions, or through derived pragmatic inferences. Language may also influence mental model construction by inducing a particular perspective, directing attention and increasing the level of activation of some contents over others (see discussion below). In the same vein, a metaphoric mapping can be acquired through exposition to cultural "reifications" of the metaphor, as those placing powerful people like professors, executives, kings or winners in higher positions on daises, buildings, thrones or podiums (Schubert, 2005).

For similar reasons, cultural practices such as orthographic direction and graphic conventions can induce horizontal conceptual mappings of linear order and time (e.g., Tversky et al, 1991), numerical sequences (Dehaene et al, 1993) and agent-patient relations and action directionality (e.g., Chatterjee et al, 1995; see the review section), even though they are just arbitrary cultural choices. Mental models of events are constructed from text, comic strips, charts and so on. These models use a left-to-right strategy as a consequence of the search for a maximally coherent model of the entire situation, including both the spatial linearisation of the input and the meaning of its parts. Reading habits also produce attentional and scanning biases which can operate on inner space when mental models are created for other reasons. As a result, the spacialization of meaning falls into place just because of pure co-occurrence coupled with the strong human tendency to build coherent mental models.

Support for this suggestion is provided by Jahn, Knauff and Johnson-Laird (2007), who showed that when participants receive a description like "a table is between the TV and a chair", they tend to form a model which locates the TV on the left, then the table in the center, and the chair on the right, although this arrangement does not necessarily follow from the premises. A current study in our lab is testing whether Arabic readers show the opposite bias in mental model construction, which would support its more than likely relation with reading habits. If so, the model construction bias will support our contention that a conceptual metaphor can be learned just by repeated experiences with fully arbitrary mappings.

Finally, it is also possible to learn radically new ways of understanding a concept for which there is already knowledge in place. Learning proceeds just as when there is no prior knowledge: a creative mental model is set up from scratch. If it succeeds, the same strategy will probably be used in similar tasks in the future, producing similar memory traces. These will create a new cluster and contribute to the development of a new conceptual schema in semantic memory. How much and how easily it will be activated in the future will depend on its effectiveness, as well as on the mediating factors listed above.

Summing up, in our view the repeated construction of coherent mental models in working memory underlies the internal organisation of concepts in semantic memory. Whatever representations are simultaneously entered into a mental model are subjected to coherence interactions that may involve cross-domain projections. Mental models leave memory traces and similar traces cluster together to form new conceptual metaphoric projections in long term semantic memory.

Metaphoric Structuring and Linguistic Relativity

As the present chapter has emphasized, there are many ways to construe internally coherent conceptual structures using the reservoire of universal image schemas. Why some languages and cultures choose a particular configuration while others choose a different one? The present theory points to three sets of causes.

Firstly, mental models are built as a tool for dealing with situations and solving problems. Only the metaphoric construals which offer useful solutions to everyday problems have the potential to be repeatedly used. Levine (1997), in his thorough description of cross-cultural variations of the non-spatial TIME IS MONEY metaphor, makes a compelling case for the social and economic usefulness of this metaphor (see also Alverson, 1996).

Secondly, the factors governing the inclusion of structural and content elements in mental models influence which subset of all potentially useful construals of abstract meanings is instantiated in a culture. Some elements have intrinsically greater salience (or activation levels) as, e.g., the vertical dimension, and these are expected to be universally more influential and less variable in the construction of abstract meanings. Other factors are expected to vary widely across languages and cultures, because of variations in the many endogenous and exogenous means by which attention is deployed to certain elements over others.

Language is a chief tool for the control of attention. Talmy (2003) mentions over 50 different linguistic mechanisms that increase or decrease attention to a certain type of linguistic entity. For example, speakers of Turkish must pay attention to whether an event has been witnessed or non-witnessed, as this distinction is obligatorily encoded in the verb flexion. Speakers of many other languages have optional ways to express this distinction, but they are not forced to do it every single time a verb is produced (Slobin, 1996). This is a linguistic attentional factor which forces an element to be included in the mental model of the situation. Other factors may exert only gradual influences (Talmy, 2003). Powerful cognitive habits may be developed because of bidirectional influences between language and attention. For example, the availability of linguistic labels directs attention to certain features of the outer world (e.g., object shape), tuning the attentional mechanism to those features and so boosting the learning of new labels based on the same features (Landau, Smith & Jones, 1998; Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002). A similar mechanism may explain the exclusive use of absolute frames of reference in languages lacking deictic and intrinsic spatial terms (see Majid, Bowerman, Kita, Haun & Levinson, 2004, for a review). The currently booming research on linguistic relativity takes as one of its foundations the idea that by means of mechanisms of this kind, languages may instill cognitive habits, therefore leading to systematic differences in the way reality is conceptualized (Hunt & Agnoli, 1991; Slobin, 1996; Gentner & Goldin-Meadow, 2003; Casasanto, 2008).

In the terms of the present theory, these cognitive habits lead to the routinee inclusion or rejection of certain elements (both structural and content) in mental models. Moreover, the theory leads to a more general prediction: cross-cultural variations in factors affecting mental model construction may lead to relativity effects even if such variations are not manifested in language. The differences in conceptual left-right biases observed across cultures using a left-to-right versus a right-to-left writing system are a relevant example.

A third factor which the present theory points at is coherence. Although in the theory there is no such a thing as a coherence mechanism to be applied to the contents of long-term memory, the fact that several abstract concepts are often simultaneously part of a given mental model will expose them to the short-term coherence mechanism. This will foster the development of clusters of conceptual metaphors which are internally consistent, even though they may be radically inconsistent with the members of another cluster. As an example, Klein's (1987) analysis of time in Toba suggests that this language distinguishes a near future, approaching the speaker from behind; a near past, going away in front of her; and a remote past and future, which are linguistically indistinguishible. In Toba, the remote past is of the same nature as the remote future, supporting a cyclical understanding of time over long periods. Klein (1987) argues that similar patterns of linguistic uses can be found in Toba's understanding of death as leading to a return to life, and in their kinship terms, which group together in a single category future relatives with those who are no longer relatives (because of divorce or death).

To sum up, the present theory suggests that the factors underlying cross-linguistic and cross-cultural differences in metaphoric structuring can be grouped into three main categories: 1) social and economic usefulness of a given mapping; 2) attentional foregrounding of their components, both structure and content, by endogenous and exogenous means, with language playing an important but not exclusive role; and 3) patterns of coalescence with other metaphoric mappings already in use in the culture. These are the same organising principles for metaphoric structuring of concepts within a single culture and language, although less variation is expected because many of these factors are kept constant in this context.

Symbol grounding through conceptual metaphors

As a closing note of a general character, it should be emphasized that the present theory represents a move from the focus on long term memory structures that characterizes most current approaches to conceptual metaphor, to a focus on working memory representations and processes.

Stability is the hallmark of the contents of long term semantic memory. Thinking of conceptual metaphors as long term memory structures leads to a view of abstract concepts as embodied through pre-wired, solid, stable connections to more basic perceptuomotor schemas. The human conceptual system would thus be analogous to a building (Figure 1), where relations of support underlie the progressive abstractness of concepts, a proposal we termed the Solid Foundations View.

However, our review of the literature suggests that available evidence supports a more flexible view. Flexibility is the hallmark of working memory and attentional processes. In our view, centered on conceptual processing taking place in working memory, content representing abstract concepts sometimes participates in projections from and to content representing more concrete domains. They are flexible projections, chosen out of the available possibilities (or even created anew) to best fit into the overall current mental model and generate the best adaptation to the situation and task at hand. In other occasions, concepts are understood in terms of other concepts which are at the same level of abstractness, or even in terms of more abstract concepts.

The important point is that all of them are mentally represented by means of concrete contents, as the mental workspace is bound to be populated only by concrete representations, however labelled. The mental space is basically a perceptual space, and its contents can be built from both the senses and long term memory, providing a grounding for the concepts residing in memory. It is also a flexible grounding: concepts are embodied at the moment of thinking about them.

The central postulates of the present theory do not say much about conceptual representation in semantic long-term memory. A possible solution to the basic categorization problem (how to decide whether a mental model entity is to be properly labelled as an instance of a given concept), when the entity has been introduced in the model as a result of activating a concept in long term memory, consists in tracing the source concept, which will provide perfect labelling (Barsalou, 1999). However, when the entity is introduced from perceptual data, the theory says nothing about how memory search and concept activation is carried out. To reiterate, the present theory is not about semantic memory but working memory. If concepts were represented in semantic memory as disembodied feature lists or propositions, it would probably make no strong difference to the central tenets of the current theory.

With the additional assumption that working memory is the entry gate to long term memory, and that mental models are saved to memory after each successful use, then the theory predicts that semantic memory representations would also be based on perceptual-motor representations to a significant extent, as proposed by Barsalou (1999). This assumption also suggests that conceptual mappings are an essential part of long-term memory. The fact that, given the activation of a conceptualization (e.g., about time passing), a particular mapping of it is observed (e.g., past-left and future-right, but not the other way around), suggests that the form of the mapping was stored in long-term memory. However, nothing suggests that conceptual mappings will necessarily proceed in the direction of concrete to abstract domains. The resulting picture of the human semantic memory system looks more like the Nest than like the Empire State (Figure 8).

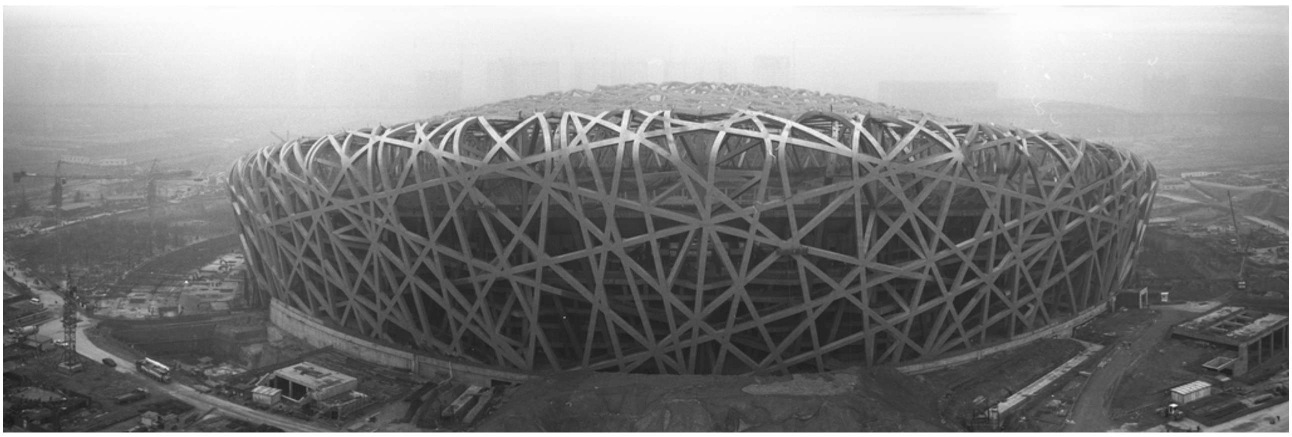

Figure 8.- Semantic memory from the Flexible Foundations View (photograph by CATIC-TEDer, some rights reserved).

Reasonable as it is, the posited connection between working and long term memory is still in need of independent evidence to substantiate it. The present theory suggests that showing that detailed mental simulations (models) are generated in language and reasoning tasks (as it has been repeateadly shown by defendants of the Simulation View, see, e.g., Glenberg & Kaschak, 2002; Richardson, Spivey, Barsalou & McRae, 2003; Stanfield & Zwaan, 2001; Zwaan et al, 2002) does not entail that their semantic memory representations take the form of perceptual symbols. Theorizing in this field is in need of developing more direct indexes of semantic representation in long-term memory. Bringing cognitive flexibility to the forefront leads to giving working memory the credit it deserves in the explanation of behavioural facts. After doing so, researchers will need to exert special care when trying to draw inferences about semantic memory from those facts.

Conclusions

In the present chapter, we have reviewed the available evidence for the Solid Foundations View of abstract concepts, with a special focus on spatial conceptual metaphors and literal-conventional-numerical language, and presented a theoretical framework which is consistent with proposals in wide areas of psychology and linguistics. This model embraces what we call a Flexible Foundations View instead. It has at its center 1) the distinction between long-term memory and a mental workspace endowed with both structure and content; 2) the notion of degree of activation as the main factor guiding inclusion in the model and interactions with other elements; and 3) a mechanism which struggles to turn the final mental model into a maximally coherent representation. The presumed design characteristics of the human mental workspace are grounded in a plausible, if simplified, account of how the universal perceptual mental space of apes may have been expanded by the acquisition of language. Finally, it includes also some simple but sensible assumptions about how learning develops from concrete episodes.

We have shown how this model is able to account for the reviewed data from several different research lines, and to provide a principled answer to some theoretically conflicting issues within the Solid Foundations tradition, chiefly the questions of 1) how an abstract concept may be simultaneously structured by means of contradictory metaphoric mappings both within a single individual and across cultures and languages; 2) how a given conceptual mapping is selected for use in the face of alternatives. The theory also provides a unified framework to think about the learning of new conceptual mappings and about the generation of cross-linguistic differences.

We have also illustrated at several points that the theory may generate non-trivial predictions. We have also provided experimental data that test one of the main assertions of the model: that both endogenous and exogenous attentional factors mediate the interaction between irrelevant spatial dimensions and relevant abstract dimensions of the processing task.

Finally, we have shown how a different view of the question of symbol grounding and embodiment arises from the present postulates, a view that emphasizes how concepts are embodied at the moment of thinking about them, of using them to solve specific problems, over the focus on long-term memory representations that characterizes most current views about this topic.

Although much work remains to be done before a fully specified computational model can be developed, we hope that this paper provides some useful ideas to foster further theoretical and empirical developments on the topics of conceptual metaphor and symbol grounding.

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