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1

Development of Metaphorical Thinking: The Role of Language

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1 Introduction

People often talk using linguistic metaphors, and *think* using mental metaphors: mappings between concrete, perceptible domains like space, force, and motion and relatively abstract, imperceptible domains like intimacy, value, and time.[1] When speakers use expressions like a *close* friendship, a *high* price, or a *long* vacation, they activate mental representations of space—the same sort of representations that enable them to perceive spatial relations among objects and to interact with the physical environment. The claim that metaphors are ways of thinking, not just ways of talking, first advanced on the basis of patterns in language (Lakoff and Johnson 1980), is

[1] The term 'conceptual metaphor' (Lakoff and Johnson 1980; 1999) is often used ambiguously, even by metaphor theorists: Sometimes the term refers to expressions in language, other times to hypothetical nonlinguistic mental representations, and still other times to pairings of linguistic and nonlinguistic mappings. These ambiguities complicate discussions of the relationship between metaphorical language and metaphorical thinking. I will distinguish the linguistic and nonlinguistic components of 'conceptual metaphors' by using the terms *linguistic metaphor* to refer to expressions in language and *mental metaphor* to refer to the implicit associations between nonlinguistic source and target domains, which are hypothesized to underlie linguistic metaphors (Casasanto 2008a). Unlike simple associations, mental metaphors consist of a system of mappings, often between two analog continuums (e.g. space and time). Mental metaphors can exist in the absence of any corresponding linguistic metaphor (see Casasanto 2009).

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now supported by a growing body of data from behavioral experiments (see Casasanto and Bottini 2013a for a review).

Where do our mental metaphors come from, and what role might language play in their development? Three answers to these questions have been proposed:

i. Mental metaphors are innate. Cross-domain mappings are the result of co-opting neural machinery that evolved for perception and action to support more abstract thinking (Pinker 1997). They are 'unlearned' (Walker et al. 2010: 21).

ii. Mental metaphors are learned via direct experience interacting with the physical world (Lakoff and Johnson 1999).

iii. Mental metaphors are learned via experience with language: Using linguistic metaphors invites speakers to construct cross-domain mappings that were not present in their pre-linguistic thought (Gentner 2001).

According to the first two proposals, language plays no role in the development of mental metaphors. On the third, language is necessary for the development of mental metaphors. Each of these three proposals could potentially explain the origins of some mental metaphors. However, in this chapter, I will argue that none of these proposals can explain how some of the most common metaphors in adults' language and thought develop, but that a complete picture begins to emerge when elements from all three proposals are combined. In some cases, it appears that (i.) *innate predispositions* may cause children (ii.) *to learn particular cross-domain correspondences as they interact with the physical world*, resulting in pre-linguistic mental metaphors that are (iii.) *subsequently shaped by experience using language*, or by other aspects of culture.

Which cross-domain mappings are found in infants' minds, how do they get there, and how might they change when children learn language? Cross-linguistic variation provides theoretical traction on questions about the origins of mental metaphors—questions that appear intractable when the mind is viewed through the lens of a single language. Experiments testing the linguistic relativity of mental representations of duration and musical pitch reveal a two-stage developmental process by which pre-linguistic mental metaphors (which may be universal) are shaped by linguistic experience, throughout our lifetimes.

2 Are Mental Metaphors Exaptations?

Ultimately, the origins of our mental metaphors may lie in the recycling of evolutionarily ancient neural systems for new uses: a process Steven Jay Gould and Elizabeth Vrba (1982) dubbed *exaptation*. Steven Pinker proposed the following sketch of how the neural substrates of perception and action could have been exapted to support abstract thought:

> Suppose ancestral circuits for reasoning about space and force were copied, the copies' connections to the eyes and muscles were severed, and references to the physical world were bleached out. The circuits could serve as a scaffolding whose slots are filled with symbols for more abstract concerns like states, possessions, ideas, and desires.
>
> (Pinker 2007: 355)

On Pinker's proposal, linguistic metaphors are 'vestigial cognitive organs' (1997: 356) that reveal evolutionary or historical connections between metaphorical source and target domains, but not active metaphorical mappings (Gentner (2001) calls this the *cognitive archaeology view*). In the years since this proposal was made, however, an abundance of experimental evidence has suggested that source-target mappings are not merely vestigial. On the contrary, source domain representations are activated highly automatically when people process target domains, and their activation has causal powers: changing how people think and feel (e.g. Casasanto 2009; Casasanto and Dijkstra 2010; Thibodeau and Boroditsky 2011). The view that source-target mappings are merely vestigial is untenable. Even if source-target links have been forged over phylogenetic time, there is clear evidence that they are activated in real time as we talk and think.

Are some source-target mappings innate? Several of the cross-domain correspondences that are reflected in adults' linguistic metaphors have been observed in infants (Walker et al. 2010; Lourenco and Longo 2011). Does that mean that these mappings are unlearned? Not necessarily—it just means they were not learned initially via language. Most of the observed mappings (e.g. between distance and duration, height and pitch, size and power) have observable correlates in the physical and social world; therefore, they could be learned from regularities in infants' physical and social experiences (see §3, below). Rather than positing that source-target mappings are innate, some researchers suggest that infants are innately predisposed to learn patterns of covariation between certain domains (e.g., core knowledge of social dominance guides infants to learn the relationship between physical size and power that gives rise to the mental metaphor Powerful is Big (Thomsen and Carey, in press)).

There is no clear evidence that any cross-domain mappings are innate (i.e. unlearned), but it seems plausible that some may be: a mappings like Powerful is Big that seem relevant for survival could be part of our mind's standard equipment. Importantly, evidence for innate mappings would still be compatible with the two-stage developmental process described here. An innate starting point for mental metaphors would not preclude a role for language in their later development – nor would their innateness imply that the same mental metaphors should be used universally by all adults.

3 Mental Metaphors from Correlations in Experience?

In the literatures on Conceptual Metaphor Theory (Lakoff and Johnson 1999) and embodied cognition, it is widely assumed that mental metaphors are not innate. Rather, they are learned on the basis of the unavoidable conflation of two types of bodily experiences: interoceptive experiences in target domains, and perceptuo-motor experiences in source domains. For example, the metaphor Affection is Warmth arises in children's minds as a consequence of feeling the physical warmth of their caretakers' bodies as they are held and comforted. According to some metaphor theorists, children initially conflate source and target (e.g. conceptually fusing warmth and affection) and later differentiate them (Johnson 1999; Lakoff and Johnson 1999).

This *theory of conflation* is often invoked, and resonates with ideas of Piaget's (1927/1969), but it has never been tested experimentally (for a detailed critique see Casasanto (2013); also Srinivasan and Carey (2010)). Just as there is no evidence that any mental metaphors are innate, there is no evidence that they are learned initially via exposure to covariation between source and target domains in the natural world during early childhood. It is clear that some source-target mappings are present in pre-linguistic infants, but to date, there are simply no data that can help us determine whether these mappings are innate or whether they are learned as infants track regularities in the physical and social environment.[2]

Abstracting away from the details of the theory of conflation, the proposal that many mental metaphors could be learned as children track patterns of correlation in their physical and social experience is appealing. To the extent that these correlations in experience are universal (based on universal aspects of the body and the world) this proposal can potentially help to explain how some mental metaphors have become enshrined in so many of the world's languages, without having to posit that the hundreds of ubiquitous mappings metaphor theorists have identified are all innate. This proposal could ultimately explain the *initial origins* of many of our basic mental metaphors.

For the present discussion about the role of language in the development of mental metaphors, however, it is not necessary to know whether the

[2] If infants were to show a cross-domain mapping reliably that did not correspond to any observable regularities in the physical or social environment, this would argue in favor of an innate basis for that mapping—though not necessarily for any other mappings.

pre-linguistic mappings that have been observed in infants are innate or learned. In either case, linguistic experience could determine how people *use* the mappings that were initially established pre-linguistically subsequently, when they talk and think.

4 Mental Metaphors from Linguistic Metaphors?

Cognitive psychologists have suggested that perhaps exposure to linguistic metaphors causes people to create mental metaphors, by inviting language users to build analogical bridges that they probably would not have constructed otherwise. For the most part, this idea has been tested for nominal metaphors like 'my lawyer is a shark' (e.g. Gentner et al. 2001): expressions that pass the grammar-school test of metaphoricity insomuch as most people will agree that they are not literally true. Such metaphors encourage a process Gentner (1983) and colleagues have called *structure mapping*, by which relations that obtain in the source domain are imported into the target domain via analogy, allowing inferences that come 'for free' in the source domain to be made about the target domain, as well. This language-mediated process can lead people to discover previously unnoticed parallels between the source and target.

Beyond nominal metaphors, the idea that language encourages us to discover cross-domain relationships has also been applied to the more frequent, 'invisible' metaphors that are the focus of most research on conceptual metaphor theory. The parade case of an invisible metaphor is the mapping between space and time. Outside of the cognitive science community, many people would deny the metaphoricity of expressions like 'my favorite scene is *coming up next*' or 'that was a *long* meeting.' Is language responsible for the construction of mental metaphors linking space and time? Lera Boroditsky (2001:20) suggested that it may be:

> Using spatial metaphors to describe time encourages structural alignment between the two domains and may cause relational structure to be imported from space to time. The mechanism for this type of metaphoric structuring may be the same as that used in analogical inference (Gentner, Bowdle, and Wolff 2001; Gentner and Wolff 1997). Language-encouraged mappings between space and time come to be stored in the domain of time. Hence, when spatiotemporal metaphors differ, so may people's ideas of time.

It is certain that temporal concepts like 'Wednesday' are learned through exposure to language and culture, and it seems possible that higher-order spatio-temporal thoughts like 'moving Wednesday's meeting *forward*' could be dependent on language, as well.

Yet, there are reasons to question whether language plays any role in the initial construction of more basic space-time mappings. For example, infants are sensitive to correspondences between spatial and temporal extent (Srinivasan and Carey 2010; Lourenco and Longo 2011). Some space-time mappings are established initially prior to any linguistic experience.

5 Analogical versus Correlational Metaphors

There appear to be (at least) two categories of mental metaphors, which can be distinguished according to the ways in which they are born and the ways that they die (or don't die). I will refer to these as *analogical metaphors* and *correlational metaphors*.[3] It is important to distinguish them for the present discussion because language plays very different roles in the development and online activation of these different kinds of mental metaphors.

The birth of correlational metaphors. As discussed above, it is easy to posit that some mental metaphors arise from correlations in direct bodily experience. Space-time mappings, for succession as well as extent, could be learned from observation of spatial changes over time. Affection and warmth co-occur in our experience; so do happiness and upright posture, intimacy and physical closeness, knowing and seeing, etc. As Lakoff and Johnson (1999) argue, it is impossible *not* to experience the co-occurrence of these source and target domains. No language required.

The birth of analogical metaphors. This is not the case, however, for lawyers and sharks. Have you *ever* seen a lawyer and a shark together? Inevitable co-occurrence cannot be what causes us to construct mappings between source and target for metaphors like 'my job is a jail' (assuming you are not a prison guard), 'my surgeon is a butcher,' or 'this book is a roller-coaster ride.' Someone had to construct these mappings via a creative act of analogy initially, but subsequently most of us construct these mappings because language invites us to do so.

The death of analogical metaphors. According to a body of experimental work by Gentner and colleagues, the way people process nominal metaphors depends critically on their novelty. The first time you ever heard someone say, 'my lawyer is a shark,' it is likely that you understood it via a process like Gentner's (1983) structure mapping. Creating a new mapping requires activating representations in both the source and target domains.

[3] This distinction overlaps with the distinction Grady (1999) proposed between metaphors based on *correlation* and *resemblance*. One point of departure lies in the difference between *analogy* vs. *resemblance*. Analogy is, essentially, relatedness without resemblance. Furthermore, the distinction proposed here is largely motivated by consideration of one body of experimental research supporting the *career of metaphor hypothesis* (Gentner et al. 2001) and a newer body of experimental research challenging its generality (Casasanto and Bottini 2013a).

Only then can relevant features of the source be transferred to the target (e.g. fierce, powerful, remorseless), and irrelevant features abstracted away (e.g. has multiple rows of teeth, breathes through gills).

Over time, this mapping process becomes unnecessary. As metaphors become conventionalized, the source domain words essentially become polysemous. For instance 'a fierce, powerful, remorseless person' becomes one of the conventional meanings of 'shark.' Gentner and colleagues (2001) call the process by which novel metaphors become polysemies *the career of metaphor*. As evidence for this process, they note that novel metaphors generate congruity effects, measurable with reaction times: People process language more efficiently when, for a given target domain, the speaker uses the same source domain consistently throughout a discourse rather than switching source domains. These congruity effects disappear, however, for highly frequent metaphors, which have become fully conventionalized.

What is important for the present discussion is that, for the kind of metaphors that appear to result from language-mediated structure mapping, source-target mappings are *only* activated when they are novel.

The death (or eternal life) of correlational metaphors. The career of metaphor hypothesis does not appear to hold for correlational metaphors. It appears that these metaphors never die (or, for the sake of source-domain consistency, never retire). Space-time metaphors provide a compelling illustration of this point. It is difficult to estimate how frequently people use words like 'long' and 'short,' 'ahead' and 'behind,' etc. to refer to time. But people talk about time a lot: 'Time' is the most frequent noun in the English language (Boroditsky and Gaby 2011). And when we talk about time, it is hard to avoid using spatial metaphors (Clark 1973). It is safe to assume that verbal space-time metaphors are very frequent, and they are completely conventionalized -- probably far more frequent and conventionalized than the 'conventional' metaphors studied in the career of metaphor literature.

And yet there is a great deal of evidence that people activate source-target mappings when they process temporal language (Boroditsky 2000; 2001; Boroditsky and Ramscar 2002; Santiago et al. 2007; Torralbo et al. 2006; Ulrich and Maienborn 2010; Weger and Pratt 2008), and even when they process temporal stimuli without using language (Casasanto 2008b; Casasanto and Boroditsky 2008; Merritt, Casasanto, and Brannon 2010). Despite the frequency and conventionality of linguistic space-time metaphors, mental metaphors linking space and time are alive and well. The same seems to be true for mental metaphors linking distance and similarity (Casasanto 2008a), height and emotional valence (Meier and Robinson 2004), and size and power (Schubert 2005), to name a few examples.

Summary of analogical vs. correlational metaphors. The distinction between correlational and analogical metaphors is supported by a doubledissociation in the way they are born and the way they die (or don't die). For analogical metaphors, source-target mappings appear to be created by a process of structure mapping that is typically initiated by exposure to metaphors in language. There is often no opportunity to learn these mappings from correlations in direct experience, since many sources and targets (e.g. lawyers and sharks) may never be experienced together (see also Grady 1999). Analogical source-target mappings are active when the metaphors are novel, but not after they become conventional: Analogical metaphors retire.

For correlational metaphors, source-target mappings could in principle be learned as children observe covariation between source and target domains, without any linguistic input. Some mappings appear to be detectable in pre-linguistic infants (see below). Even for highly frequent, totally conventional metaphors (e.g. Temporal Extent is Spatial Extent), source-target mappings continue to be activated automatically when people process the target domains: Correlational metaphors may never retire.

What are the implications of the correlational / analogical distinction for the role of language in the development of mental metaphors? The parade cases of primary metaphor (e.g. Similarity is Closeness; see Casasanto 2008a) appear to be correlational, not analogical: They could in principle arise pre-linguistically, and they do not appear to retire. On this analysis, correlational metaphors do not depend on language – at least not for their *initial* development.

6 Hierarchical Mental Metaphors Theory

This analysis creates a problem. Analogical metaphors are based on linguistic experience, so it is easy to see how people who are exposed to different linguistic metaphors would develop correspondingly different mental metaphors, as a consequence (e.g. see suggestion from Boroditsky 2001, above). By contrast, correlational metaphors are based on regularities in the physical world that people should experience universally, so the resulting mental metaphors should be universal. I have argued that at least some space-time metaphors (for example) are correlational, and yet there is now a great deal of evidence that they are *not* universal (Boroditsky 2001; Casasanto 2008b; Fuhrman and Boroditsky 2010; Núñez and Sweetser 2006; Ouellet et al. 2010; Tversky, Kugelmass, and Winter 1991). How can correlational mental metaphors be grounded in universal experiences, yet also differ in people's minds according to the metaphors in their languages?

This problem dissolves if we posit that mental metaphors are constructed hierarchically. According to Hierarchical Mental Metaphors Theory (HMMT; Casasanto and Bottini 2013b), correlational mental metaphors develop in two stages, the second of which may extend throughout the lifetime. The mental metaphors that adults typically use are specific instances of more general families of mappings. These families may be evident in behavior from infancy, and reflect regularities in humans' experiences of the physical and social world, many of which may be universal. As children are exposed to peculiar aspects of their languages, cultures, or even their own bodies, certain mappings from a given source-target family become strengthened through repeated use, which weakens 'sibling' mappings as a consequence. The result is that people tend to think in language-specific, culture-specific, or body-specific mental metaphors: Relativity emerges from universals.

Two sets of studies illustrate the process by which language-specific mental metaphors arise from (presumably) universal mappings between space and time and between space and pitch.

7 Mental Metaphors for Duration and Musical Pitch

English speakers tend to express duration in terms of spatial extent (e.g. a *long* time, like a *long* rope). This uni-dimensional mapping has been assumed to be universal: a consequence of the unidirectional flight of time's arrow, and of universal aspects of our bodily interactions with the environment (Clark 1973). Indeed, it is difficult to avoid using uni-dimensional spatial metaphors when talking about the durations of events in English. Try replacing the word 'long' in the phrase 'a *long* meeting' with a synonym. Words like lengthy, extended, protracted, or drawn out would suffice, all of which express time in terms of linear extent. In contrast with English speakers, Greek speakers tend to express duration in terms of volume or amount (e.g. a *lot of* time (*tr. poli* ora), like a *lot of* water (*tr. poli* nero)). Greek speakers *can* express duration in terms of extent, just as English speakers can make use of volume or amount, but volume metaphors are more frequent and productive in Greek, whereas extent metaphors are more frequent and productive in English (Casasanto et al. 2004; Casasanto 2008b).

Does the tendency to talk about duration in terms of 1-dimensional or 3-dimensional space influence the way people tend to think about it? To find out, in one set of experiments English and Greek speakers were given non-linguistic psychophysical tests of their ability to estimate duration (Casasanto et al. 2004; Casasanto 2008b). Participants were asked to reproduce the durations of stimuli they saw on a computer screen (i.e. lines gradually extending across the screen or containers gradually filling up) while ignoring the spatial extent of the lines (distance interference) or the fullness of the containers (volume interference). English speakers had difficulty screening out interference from spatial distance when estimating duration:

Lines that traveled a longer distance were mistakenly judged to take a longer time than lines that traveled a shorter distance. But their time estimates were relatively unaffected by irrelevant volume information. Greek speakers showed the opposite pattern: They had more difficulty screening out interference from volume, so fuller containers were judged to remain on the screen for more time than emptier containers, but their judgments were relatively unaffected by the spatial extent of lines. The pattern of distance and volume interference in these nonlinguistic psychophysical tasks reflects the relative prevalence of distance and volume metaphors for duration in English and Greek.

The cross-linguistic comparison between Greek and English speakers shows a correlation between temporal language and temporal thinking. Can language play a causal role in shaping nonlinguistic time representations? To test whether using volume metaphors in language can change the way people think about duration, the experimenters trained English speakers to use Greek-like metaphors for time (Casasanto 2008b). After about 20 minutes of exposure to these new metaphors, the effect of irrelevant volume information on English speakers' nonlinguistic duration estimates was statistically indistinguishable from the effect found in native Greek speakers. Together, these data show that people who use different temporal metaphors in their native languages conceptualize time the way they talk about it, even when they are not using language. Furthermore, linguistic experience can play a causal role in shaping mental representations of time. Producing or understanding spatio-temporal language like a Greek speaker, even for a few minutes, can cause English speakers to think about time differently, using a different kind of spatial scaffolding.

The psychophysical paradigm used to establish differences in temporal thinking between English and Greek speakers has been extended to probe cross-linguistic differences in people's mental representations of musical pitch. Pitch may be less abstract than time insomuch as it can be perceived directly with the ears. Yet, pitch may still be relatively abstract compared to space, and to the objects and actions we localize in space, which can often be perceived multimodally via some combination of sound, sight, touch, and smell.

Like English, Dutch describes pitches as 'high' (hoog) or 'low' (laag), but this is not the only possible spatial metaphor for pitch. In Farsi, high pitches are 'thin' (nāzok) and low pitches are 'thick' (koloft). Dutch and Farsi speakers' performance on non-linguistic pitch reproduction tasks reflects these linguistic differences (Dolscheid, Shayan, Majid, and Casasanto 2013). Participants were asked to reproduce the pitch of tones that they heard in the presence of irrelevant spatial information: lines that varied in their height (height interference task) or their thickness (thickness interference task). Dutch speakers' pitch estimates showed stronger cross-dimensional interference from spatial height, and Farsi speakers' from the thickness of visually presented stimuli. This effect was not explained by differences in accuracy, or in musical training. When trained to talk about pitches using Farsi-like metaphors (e.g. a tuba sounds thicker than a flute) for 20-30 minutes, Dutch speakers' performance on the non-linguistic thickness interference task became indistinguishable from native Farsi speakers'. Experience using one kind of spatial metaphor or another in language can have a causal influence on non-linguistic pitch representations.

What role is spatial language playing in shaping non-linguistic representations of time and pitch? Is language creating cross-domain associations, or is linguistic experience modifying pre-linguistic mental metaphors? Pre-linguistic infants intuit a link between more duration and more spatial extent (Srinivasan and Carey 2010), and also between more duration and more size (Lourenco and Longo 2011). Thus, both the distance-duration mapping that is most prevalent in English and the volume-duration mapping that is most prevalent in Greek may be present pre-linguistically. Likewise, infants as young as four months old are sensitive to the height-pitch mapping found in Dutch-speaking adults (but not in Farsi-speaking adults), and also to the thickness-pitch mapping found in Farsi-speaking adults (but not in Dutch-speaking adults; Dolscheid, Hunnius, Casasanto, and Majid 2012). There is no need, therefore, to posit that using linguistic metaphors causes people to construct these mappings *de novo*.

Together, these infant and adult data support a developmental story with two chapters, as posited by HMMT. First, children represent duration via a family of spatial mappings, which includes mappings from both spatial length and volume. Likewise, they represent pitch via mappings from both height and thickness. These initial mappings may be universal, based either on innate cross-domain correspondences (Walker et al. 2010) or on early-learned correlations between source and target domains in children's experience with the physical world (Lakoff and Johnson 1999). The distance-duration and volume-duration mappings could be learned by observing that more time passes as objects travel farther distances and as quantities accumulate in 3-dimensional space. Height-pitch mappings could be learned from seeing (or feeling) the larynx rise and fall as people produce higher and lower pitches with their voices. Thickness-pitch mappings could be learned from observing the natural correlation between the size of an object or animal and the sound that it makes (imagine the sound made by banging on a soda can vs. an oil drum).

Later, linguistic experience modifies these pre-linguistic source-target mappings. Suppose each time we use a linguistic metaphor like 'a long meeting' or 'a high soprano' we activate the corresponding mental metaphor. Repeatedly activating one source-target mapping instead of another (e.g. height-pitch instead of thickness-pitch) should strengthen the activated mapping and, as a consequence, weaken the competing mapping via competitive learning (Casasanto 2008b; Dolscheid et al. 2013). This process of strengthening one spatial mapping during language use, at the expense of the alternative spatial mapping, may explain how universal space-time and space-pitch mappings in infants become language-specific mappings in adults.

The hierarchical structuring of correlational mental metaphors may help to explain how source-target mappings can be important for our representations of target domains but also surprisingly flexible. For example, according to HMMT, Dutch speakers could be trained to think like Farsi speakers so quickly because they did not have to *learn* the thickness-pitch mapping during their 20-30 minutes of using Farsi-like linguistic metaphors. Rather, this linguistic training strengthened the association between thickness and pitch that was present in participants' minds from infancy (as indicated by data from Dutch 4-year olds), but which had been weakened as a consequence of their frequent use of height-pitch metaphors in language.

One prediction of HMMT is that specific source-target mappings should be easy to activate via linguistic training so long as they are members of one of the families of source-target mappings encoded in our minds (over phylogenetic or ontogenetic time) on the basis of observable source-target correspondences in the world. Mappings that are not members of a pre-linguistically established family (and that do not reflect correlations in our experience) should be relatively hard to activate via training, because these mappings would need to be created, not just strengthened.

In a test of this prediction, Dutch speakers were trained to used a thickness-pitch mapping that is the reverse of the mapping found in Farsi, and in the natural world: thin=low and thick=high. These 'reverse-Farsi' trained participants received the same amount of training as the participants trained to use the Farsi-like mapping. Whereas Farsi-like training had a significant effect on participants' nonlinguistic pitch representations, reverse-Farsi training had no effect (Dolscheid et al. 2013). Thus, brief linguistic experience caused participants to use the thickness-pitch mapping that reflects correlations between thickness and pitch in the world (and is evident in prelinguistic infants). Yet, the same amount of linguistic experience was not effective at instilling the opposite thickness-pitch mapping, which has no obvious experiential correlates, and is therefore not predicted to be among the pre-linguistically established space-pitch mappings.

8 Conclusions

Language plays different roles in the development of different kinds of metaphorical mappings. Language appears to play a causal role in establishing analogical metaphors (e.g. Lawyers are Sharks), which are only processed via active source-target mappings when they are novel (Gentner et al. 2001). By contrast, language may not play any role in initially establishing correlational metaphors (e.g. Time is Space), some of which have been detected in pre-linguistic infants, and which persist as active source-target mappings in adults despite being highly conventional and very frequent.

Correlational metaphors are grounded in patterns of body-world interaction that may be universal. Yet, there is cross-linguistic variation in the way some target domains are metaphorized in language, and there is corresponding variation in the mental metaphors that members of different language communities tend to use. Any apparent tension between the *universality* of correlational mappings and their *linguistic relativity* can be resolved, however, by positing that adults' mental metaphors are constructed hierarchically. The specific mappings we tend to use (e.g. Duration is Spatial Extent for English speakers; Duration is Volume for Greek speakers), which are conditioned by language, are members of a superordinate family of source-target mappings (e.g. More Time is More Space). These superordinate mappings are conditioned by relationships between source and target domains in our experience of the natural world. Specific mappings that are absent from one's native language (and from one's habitual thought) can be activated quickly with exposure to new linguistic metaphors so long as the 'new' mappings are members of a pre-linguistically established family of mappings. As such, our mental metaphors are language-specific at one level of analysis but may be universal at another.

References

Boroditsky, L. 2000. Metaphoric structuring: Understanding time through spatial metaphors. *Cognition* 75(1): 1–28.

Boroditsky, L. 2001. Does language shape thought? English and Mandarin speakers' conceptions of time. *Cognitive Psychology* 43: 1–22.

Boroditsky, L. and A. Gaby. 2010. Remembrances of Times East: Absolute Spatial Representations of Time in an Australian Aboriginal Community. *Psychological Science* 21(11): 1635–1639.

Boroditsky, L., and M. Ramscar 2002. The roles of body and mind in abstract thought. *Psychological Science* 13(2): 185–189.

Casasanto, D. 2008a. Similarity and proximity: when does close in space mean close in mind? *Memory and Cognition* 36: 1047–1056.

Casasanto, D. 2008b. Who's afraid of the Big Bad Whorf? Cross-linguistic differences in temporal language and thought. *Language Learning* 58(1): 63–79.

Casasanto, D. 2009. Embodiment of abstract concepts: good and bad in right- and left-handers. *Journal of Experimental Psychology: General* 138: 351–367.

Casasanto, D. 2013. Experiential Origins of Mental Metaphors: Language, Culture, and the Body. *Metaphorical Thought in Social Life,* eds. M. Landau, M.D. Robinson, and B. Meier. Washington, DC: American Psychological Association Books.

Casasanto, D., and L. Boroditsky. 2008. Time in the mind: Using space to think about time. *Cognition* 106: 579–593.

Casasanto, D., L. Boroditsky, W. Phillips, J. Greene, S. Goswami, S. Bocanegra-Thiel, I. Santiago-Diaz, O. Fotakopoulu, R. Pita and D. Gil. 2004. How deep are effects of language on thought? Time estimation in speakers of English, Indonesian, Greek, and Spanish. *Proceedings of the 26th Annual Conference of the Cognitive Science Society,* eds. K. Forbus, D. Gentner, and T. Regier, 186–191. Chicago, IL.

Casasanto, D. and R. Bottini, 2013a. Spatial language and abstract concepts. *Wiley Interdisciplinary Reviews*. In press.

Casasanto, D. and R. Bottini. 2013b. Mirror reading can reverse the flow of time. *Journal of Experimental Psychology: General*. In press.

Casasanto, D. and K. Dijkstra. 2010. Motor action and emotional memory. *Cognition* 115: 179–185.

Clark, H. H. 1973. Space, time, semantics and the child. *Cognitive Development and the acquisition of language,* ed. T. E. Moore, 27–63. New York, NY: Academic Press.

Dolscheid, S., S. Hunnius, D. Casasanto, and A. Majid. 2012. The sound of thickness: Prelinguistic infants' associations of space and pitch. *CogSci 2012: Proceedings of the 34th Annual Meeting of the Cognitive Science Society,* eds. N. Miyake, D. Peebles, and R. P. Cooper, 306–311. Austin, TX: Cognitive Science Society.

Dolscheid, S., S. Shayan, A. Majid, and D. Casasanto. 2013. The thickness of musical pitch: psychophysical Evidence for Linguistic Relativity. *Psychological Science*. DOI: 10.1177/0956797612457374

Fuhrman, O., and L. Boroditsky. 2010. Cross-cultural differences in mental representations of time: evidence from an implicit non-linguistic task. *Cognitive Science* 34*:* 1430–1451.

Gentner, D. 1983. Structure-mapping: a theoretical framework for analogy, *Cognitive Science* 7: 155–170.

Gentner, D. 2001. Spatial metaphors in temporal reasoning. *Spatial schemas and abstract thought*, ed. M. Gattis, 203–222. Cambridge: MIT Press.

Gentner, D., B. Bowdle, P. Wolff, and C. Boronat. 2001. Metaphor is like analogy. *The analogical mind: Perspectives from cognitive science,* eds. D. Gentner, K.J. Holyoak and B.N. Kokinov, 199–253. Cambridge: MIT Press.

Gentner, D., and P. Wolff. 1997. Alignment in the processing of metaphor. *Journal of memory and language* 37(3): 331–355.

Gould, S. and E. Vrba 1982. Exaptation—a missing term in the science of form. *Paleobiology* 8: 4–15.

Grady, J. 1999. A typology of motivation for conceptual metaphor: correlation vs. resemblance. *Metaphor in Cognitive Linguistics,* eds. G. Steen and R. Gibbs, 79–100. Philadelphia: John Benjamins.

Johnson, C. 1999. Metaphor vs. conflation in the acquisition of polysemy: The case of *see*. *Cultural, psychological, and typological issues in cognitive linguistics,* eds. H. Massako, C. Sinha, and S. Wilcox, 155–170. Amsterdam: John Benjamins.

Lakoff, G., and M. Johnson. 1980. *Metaphors we live by*. Chicago: Chicago University Press.

Lakoff, G., and M. Johnson. 1999. *Philosophy in the flesh: the embodied mind and its challenge to western thought*. Chicago, IL: University of Chicago Press.

Lourenco, S. F., and M. R. Longo. 2011. Origins and the development of generalized magnitude representation. *Space, time, and number in the brain: searching for the foundations of mathematical thought, eds*. S. Dehaene and E. Brannon, 225–244. Amsterdam: Elsevier.

Meier, B. P., and M. D. Robinson. 2004. Why the Sunny Side Is Up Associations Between Affect and Vertical Position. *Psychological Science* 15(4): 243–247.

Merritt, D. J., D. Casasanto, and E. M. Brannon. 2010. Do monkeys think in metaphors? Representations of space and time in monkeys and humans. *Cognition* 117(2): 191–202.

Núñez, R. and E. Sweetser. 2006. With the future behind them: Convergent evidence from Aymara language and gesture in the crosslinguistic comparison of spatial construals of time. *Cognitive Science* 30: 401–450.

Ouellet, M., J. Santiago, Z. Israeli, and S. Gabay. 2010. Is the future the right time? *Experimental Psychology* 57: 308–314.

Piaget, J. 1927/1969. *The child's conception of time*. New York, NY: Ballantine Books.

Pinker, S. 1997. *How the mind works*. New York, NY: Norton.

Santiago, J., J. Lupáñez, E. Pérez, and M. J. Funes. 2007. Time (also) flies from left to right. *Psychonomic Bulletin and Review* 14(3): 512–516.

Schubert, T. 2005. Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology* 89: 1–21.

Srinivasan, M., and S. Carey. 2010. The long and the short of it: on the nature and origin of functional overlap between representations of space and time. *Cognition* 116*:* 217–241.

Thibodeau, P. H. and L. Boroditsky. 2011. Metaphors we think with: The role of metaphor in reasoning. *PLoS One* 6(2).

Thomsen, L. and S. Carey. In Press. Core Cognition of Social Relations. *Navigating the Social World: What Infants, Children, and Other Species Can Teach Us,* eds. M. Banaji and S. Gelman. Oxford: Oxford University Press.

Torralbo, A., J. Santiago, and J. Lupiáñez. 2006. Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science* 30(4): 745–757.

Tversky, B., S. Kugelmass, and A. Winter. 1991. Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology* 23(4): 515–557.

Ulrich, R., and C. Maienborn. 2010. Left–right coding of past and future in language: The mental timeline during sentence processing. *Cognition* 117(2): 126–138.

Walker, P., J. G. Bremner, U. Mason, J. Spring, K. Mattock, A. Slater, and P. Johnson. 2010. Preverbal infants' sensitivity to synaesthetic cross-modality correspondences. *Psychological Science* 21: 21–25.

Weger, U. W. and J. Pratt. 2008. Time flies like an arrow: Space–time compatibility effects suggest the use of a mental timeline. *Psychonomic Bulletin and Review* 15(2): 426–430.