Overview

Spatial language and abstract concepts

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What is the relationship between spatial language and abstract concepts? When people talk about abstract things that they can never see or touch, they often use spatial metaphors (e.g., a *long* vacation, a *high* price, a *close* friendship). According to theories of metaphorical mental representation, linguistic metaphors reflect underlying mental metaphors. Yet, behavioral experiments show that this is only one of the possible relationships between spatial metaphors in language and our spatial conceptualizations of abstract domains. In some cases, linguistic metaphors not only reflect speakers' thoughts, they also change those thoughts, such that people who use different linguistic metaphors rely on correspondingly different mental metaphors. Alternatively, spatial metaphors in language may reflect the way people conceptualize an abstract domain *in some circumstances*, but not in others. Finally, spatial language may reflect the way an abstract domain is typically conceptualized *by some people*, but not by others. There is no single relationship between spatial language and abstract concepts. Discovering whether (and under what conditions) a linguistic metaphor corresponds to a mental metaphor can illuminate the ways in which our interactions with the physical and social environment shape our mental lives.

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INTRODUCTION

How do we think about abstract entities like time, intelligence, or happiness that have no physical properties we can perceive through the senses or act upon with the muscles? Part of the answer appears to be that we think in metaphors: often, spatial metaphors. Prices are 'high' or 'low'; numbers are 'big' or 'small'; relationships are 'close' or 'distant'; scientific questions can be 'narrow' or 'broad'; theoretical insights can be 'shallow' or 'deep'.

According to metaphor theorists, metaphors are more than just ways of talking.[1–5] Our abstract thoughts are constructed, in part, metaphorically. When we think about abstract domains like prices, numbers, relationships, questions, and theories, we activate spatial representations: the same sorts of representations of height, size, proximity, breadth, and depth that allow us to perceive and understand these spatial dimensions of concrete objects in the physical world.

This proposal was first inspired by the ubiquity of spatial metaphors in language. As Benjamin Whorf noted, 'we can hardly refer to the simplest nonspatial situation without constant resort to [spatial] metaphors'.[6] Some cognitive scientists in the 20th century interpreted the prevalence and systematicity of metaphorical language as evidence for metaphorical thought.[1,5,7] Others suggested alternative, nonmetaphorical explanations for the fact that people often use the same words literally and figuratively (e.g., perhaps words like 'high' and 'low' are simply polysemous, and have some spatial meanings and other nonspatial meanings).[8–10] On the basis of patterns in language, alone, it is not possible to determine whether people *think* about abstract ideas metaphorically, the way they talk about them.

Since the beginning of the 21st century, the idea that people think metaphorically, and that

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metaphorical language provides a window on our abstract concepts, has been tested in dozens of behavioral experiments. On the basis of their results, it is now possible to observe a close correspondence between metaphorical language and metaphorical thinking in some instances, but a striking divergence in others.

CORRESPONDENCE BETWEEN SPATIAL LANGUAGE AND ABSTRACT THOUGHT

Talking in spatial metaphors means using spatial words to describe nonspatial entities, states, or relationships. Elevators and airplanes can go up and down, literally. By contrast, the price of eggs, the rate of unemployment, the popularity of a politician, the value of the Yen, and the temperature of the air outside your window can only go 'up' and 'down' metaphorically.

What does it mean to *think* in spatial metaphors? According to some theorists, our conceptualizations of abstract domains like value and popularity are partly constituted by mental metaphors: implicit associations between nonlinguistic mental representations in concrete *source domains* like space and relatively abstract or unfamiliar *target domains*.[1,3] Typically, source domains can be experienced through perception and motor action, whereas target domains can only be experienced through introspection or interoception (the sense of one's internal bodily states). Target domain representations may be vague or fleeting compared to source domain representations, and may be more difficult to describe in words or to visualize in mental images. Metaphors import the inferential structure of space into nonspatial target domains, allowing us to describe, visualize, measure, and compare abstract entities as if they were concrete objects that had height, depth, or breadth.[1,2,7,11]

When Metaphors in Language Reflect Metaphorical Thinking

According to metaphor theorists, when we think about a target domain we automatically activate source domain representations. In many cases, this assumption is supported: people often think about abstract entities metaphorically, the way they talk about them.

For example, in English and other languages metaphorical expressions link positive and negative emotional valence with the top and bottom of a vertical spatial continuum[1,7]: a happy person is 'high on life', but a sad person is 'down in the dumps'; some students are at the 'top of the class', but others are at the 'bottom of the barrel'. These linguistic expressions correspond to nonlinguistic mental metaphors associating vertical space and valence. People are faster to judge the valence of positive words like 'loyal' when they appear at the top of a screen, and negative words like 'cruel' when they appear at the bottom.[12] The valence of pictures biases people's memories for their locations. Participants tend to misremember positive pictures as having appeared higher on a computer screen than negative pictures presented in the same locations.[13] Similarly, when asked to recall the locations on a map where positive and negative incidents occurred (e.g., winning a prize versus having an accident), the locations of positive events tend to be shifted upward in people's memories, and the locations of negative events shifted downward.[14]

Across cultures, people spontaneously elevate the chest or raise the arms above the head to express pride, and hang the head or slump the shoulders to express shame. Accordingly, upward- and downward-directed bodily actions can influence the retrieval of emotional memories. People retrieve positive memories more efficiently when smiling and sitting erect, and negative memories more efficiently when frowning and slumping down.[15] Body postures and facial expressions are socially meaningful, but even meaningless motor actions can influence the valence of people's memories. In one experiment, participants were assigned to move marbles either upward or downward, from one cardboard box to another, while retrieving and retelling stories from their past. They recounted more positive memories during upward movements, and more negative memories during downward movements (Figure 1).[16]

Even congenitally blind people express pride and shame with upward and downward postures and gestures, even though they have never seen these behaviors modeled by other people, suggesting that the propensity to link up and down with positive and negative may be innate.[17] According to some theorists, 'Good is Up' metaphors in language reflect a universal association between directed motor actions and subjective emotional states.[1,7]

How Metaphors in Language Can Shape Metaphorical Thinking

In some cases, metaphors in language do more than reflect preexisting links between source and target domains: they also influence which mental metaphors people tend to use to conceptualize universal aspects of our experience.

In English and other languages, we often talk about time using spatial metaphors. Whereas English

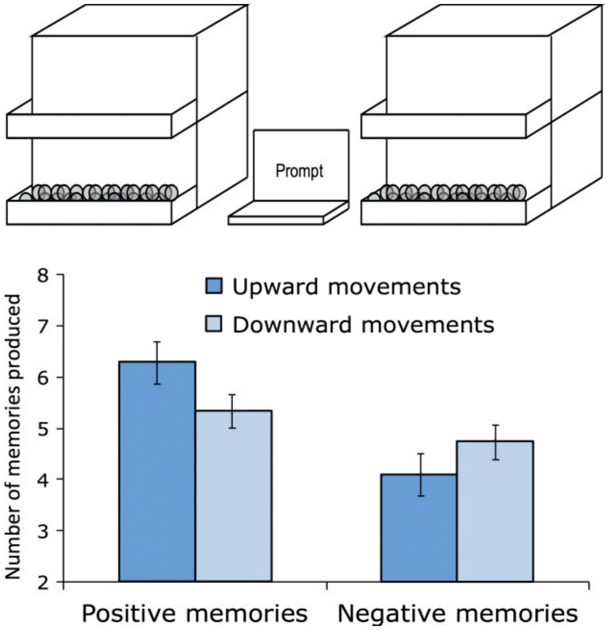

FIGURE 1 | Directed motor actions influence emotional memories. When asked to move marbles from the bottom box to the top box (or vice versa), participants were more likely to retell positive autobiographical memories during upward movements and negative memories during downward movements, consistent with linguistic metaphors linking 'up' with 'good' and 'down' with 'bad'. (Reprinted with permission from Ref 16. Copyright 2010 Elsevier)

metaphors suggest that time flows horizontally along the front-back axis (e.g., the future is *ahead* and the past is *behind* us), Mandarin Chinese also uses vertical metaphors: a month earlier is 'the *up* month' and a month later is 'the *down* month'.[18] In one study, horizontal spatial primes facilitated English speakers' judgments of sentences about temporal sequences (e.g., 'April comes *earlier* than May') more than vertical primes, but the opposite pattern of priming was found in Mandarin speakers. This pattern of reaction times is consistent with the difference in the prevalence of horizontal versus vertical metaphors for time in English and Mandarin.[19–21] To test whether linguistic experience could affect these mappings, the experimenters trained a new group of English speakers to use Mandarin-like vertical spatial metaphors in which earlier and later events were described as occurring above or below one another (e.g., 'Nixon was president *above* Clinton'). After exposure to about a 100 of these sentences, English speakers showed a pattern of priming similar to the pattern observed in native Mandarin speakers.[19,a]

Beyond influencing how people process temporal sentences, Is it possible that metaphors in language can even influence people's basic, nonlinguistic representations of time? To find out, in one set of experiments English and Greek speakers were given nonlinguistic psychophysical tests of their ability to estimate duration.[22,23] English tends to express duration in terms of linear distance (e.g., a *long* time, like a *long* rope). By contrast, Greek tends 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)]. 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 or the fullness of the containers. 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 (Figure 2). The pattern of distance and volume interference in these nonlinguistic psychophysical tasks reflected the relative prevalence of distance and volume metaphors for duration in English and Greek.

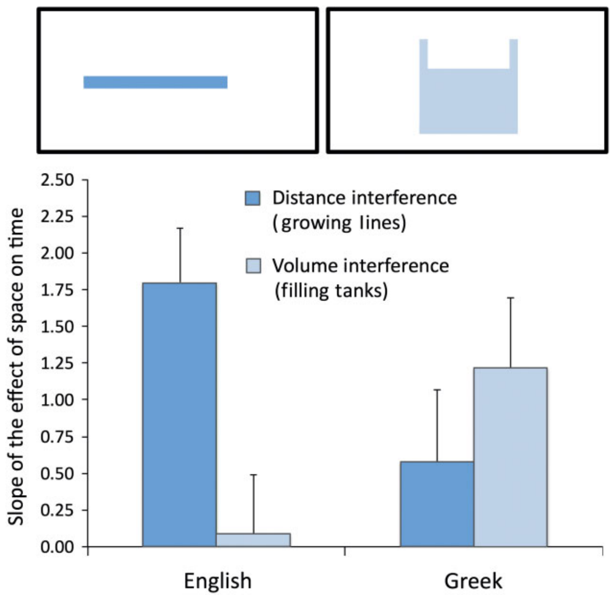

FIGURE 2 | Space–time metaphors in language influence nonlinguistic mental representations of time. Participants reproduced the durations of temporal intervals in the presence of irrelevant spatial information. English speakers' duration estimates were influenced more strongly by spatial length than by volume, but Greek speakers showed the opposite pattern, consistent with space–time metaphors for duration in English and Greek. (Reprinted with permission from Ref 22. Copyright 2004 Cognitive Science Society)

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.[23] After about 20 min 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. 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 experiences can play a causal role shaping mental representations of time. Producing or understanding spatiotemporal language like a Mandarin speaker or 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.[24,b] 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 nonlinguistic pitch reproduction tasks reflected these linguistic differences. 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 (in one task) or their thickness (in the other 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 between Dutch and Farsi speakers in accuracy or in musical training. When Dutch speakers were trained to talk about pitches using Farsi-like metaphors (e.g., a tuba sounds *thicker* than a flute), their performance on the nonlinguistic 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 nonlinguistic pitch representations.

These experimental results raise a question: What role might spatial language play in shaping nonlinguistic representations of time and pitch? Is language creating cross-domain associations, or is linguistic experience modifying pre-linguistic mental metaphors? Studies show that pre-linguistic infants intuit a link between more duration and more space.[24] Similarly, infants as young as 4-months old are sensitive to the height-pitch mapping found in Dutch-speaking adults (but not in Farsi-speaking adults),[25] and also to the thickness-pitch mapping found in Farsi-speaking adults (but not in Dutch-speaking adults).[26]

Together, these infant and adult data suggest a developmental story with two chapters. First, children represent duration via mappings from *both* spatial length and volume, and represent pitch via mappings from *both* height and thickness. These initial mappings are presumably universal, based either on innate cross-domain correspondences[25] or on early-learned correlations between source and target domains in children's experience with the physical world.[7] 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 3D space. Height-pitch correspondences could be learned from seeing (or feeling) the larynx rise and fall as people produce higher and lower pitches with their voices. Thickness-pitch correspondences could result from 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 versus 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.[23,27] 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.

This two-stage process may also help to explain the rapidity with which adults can be trained to use a mental metaphor not usually encoded (or not preferred) in their native language. For example, when Dutch speakers learn to talk like Farsi speakers, they are not learning a *new* space–pitch association. Rather, talking about pitches in terms of thickness in the laboratory temporarily strengthens their prelinguistic thickness-pitch mapping, which had been weakened (but not lost) as a consequence of habitually using height-pitch metaphors in Dutch. On this account, the capacity to represent a domain like time or pitch in terms of space may be universal, even though the habit of representing the target domain in a particular way, using a particular spatial schema, is conditioned by language.

DIVERGENCE BETWEEN SPATIAL LANGUAGE AND ABSTRACT THOUGHT

The studies reviewed so far suggest a tight coupling between spatial language and the spatial representations that scaffold mental representations in nonspatial domains. Yet, other studies show clear divergence between the way people talk and the way they think. People use space to conceptualize abstract domains, but not always in the ways their linguistic metaphors suggest.

Spatial Metaphors in the Mind That Are Absent from Spatial Language

Spatial metaphors for time are very common, but no known spoken language uses the lateral (left–right) axis to talk about time conventionally: Monday comes *before* Tuesday, not *to the left* of Tuesday.[28–30] Yet, despite the total absence of left–right metaphors in spoken language, there is strong evidence that people implicitly associate time with left–right space, and that the direction in which events flow along people's imaginary timelines varies systematically across cultures. In a seminal study, children and adults were asked to place stickers on a page to indicate where breakfast and dinner should appear relative to the lunch sticker, in the middle of the page.[31] Whereas English speakers placed breakfast on the left and dinner on the right of lunch, Arabic speakers preferred the opposite arrangement. This pattern was corroborated by reaction time tasks. English- and Hebrew-speaking participants judged whether the second of two pictures showed an earlier or later stage of an unfolding event. English speakers' judgments were fastest when 'earlier' was mapped to the left button and 'later' to the right, but Hebrew speakers showed the opposite pattern.[32,33]

These experimental data reflect patterns that can be seen in more naturalistic behavior, as well. When English speakers produce co-speech gestures they appear to use the lateral axis for time much more often than the sagittal axis.[29,30,34] Earlier times are on the left and later times on the right of the gesturer's body-centered space. Speakers gesture on the lateral axis even when they are using explicitly sagittal space–time metaphors in language, gesturing leftward (not backward), for example, while saying 'farther *back*' in time.[29]

These data raise two questions: Where does the left–right mapping of time come from, and under what conditions do people represent temporal sequences laterally as opposed to sagittally? The left–right mapping of time has been hypothesized to arise from our experience with the written word. As we read or write, we move our eyes, hand, and attention 'through' both space and time, from left to right for some orthographies (e.g., Roman script) and from right to left for others (e.g., Arabic script). To find out whether experience using one orthography or another is sufficient to determine the direction of the mental timeline, Dutch participants were asked to perform a space–time congruity task on stimuli written in standard (left-to-right) Dutch orthography, mirror-reversed orthography, or orthography that was rotated either 90° upward or downward.[35] When participants judged temporal phrases written in standard orthography, their reaction times were consistent with a rightward-directed mental timeline. After a few minutes of exposure to mirror-reversed orthography, however, participants showed the opposite pattern of reaction times; their implicit mental timelines were reversed (Figure 3). When standard orthography was rotated 90° upward or downward, participants' mental timelines were rotated, accordingly. These data suggest that experience reading is sufficient to determine the direction of people's implicit mental timelines, but do not rule out the possibility that other culture-specific practices (e.g., gesturing, using calendars, or written timelines) could influence people's lateral representations of time, as well.

When do people represent time sagittally (as in linguistic metaphors) versus laterally (as in nonlinguistic cultural conventions)? Data from spontaneous gestures provide clues. In English speakers, there appears to be an association between the axis people use for gestures and the type of temporal relationship encoded in their co-occurring speech. Lateral gestures were found to be most common during *sequence language*: speech about sequences of events whose order can be understood independent of any particular speaker or observer (e.g., Monday comes before Tuesday). Sagittal gestures were more common during *deictic language*: speech about events whose order had to be understood with respect to a particular 'now' point (e.g., tomorrow will be Tuesday).[29,36] The linkage of *sequence time* with the lateral axis and of *deictic time* with the sagittal axis found in English speakers' spontaneous gestures echoes a pattern found in conventional temporal expressions in American Sign Language.[37]

Spatial Metaphors in the Mind That Contradict Spatial Language

Across many languages, 'good' is associated with 'right' and 'bad' with 'left', as is evident from positive and negative expressions like 'my right-hand man' and 'two left feet', and from the meanings of English words derived from the Latin for right (*dexter*) and

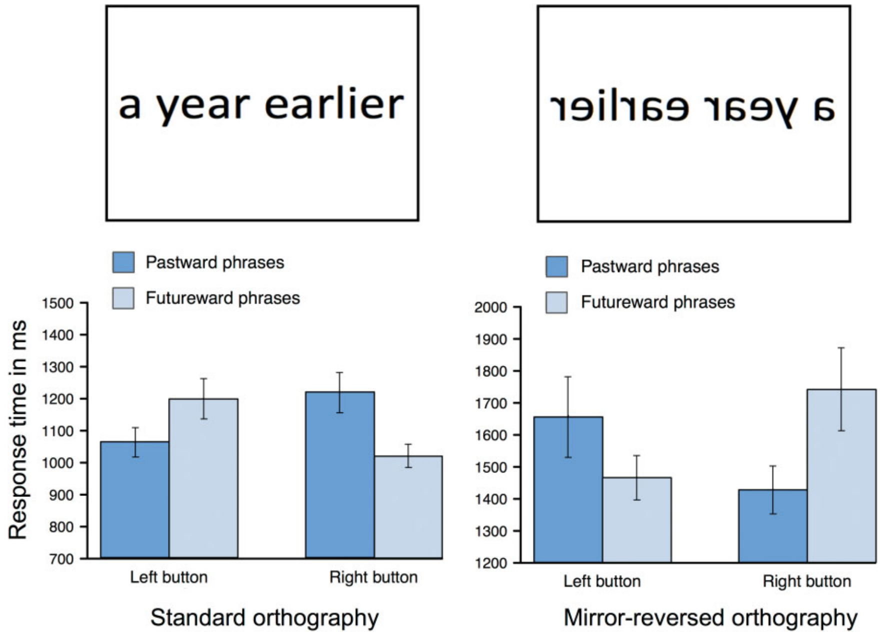

FIGURE 3 | Reading experience can reverse the flow of time in people's minds. When exposed to standard Roman orthography, Dutch speakers' judgments of temporal phrases revealed a rightward-directed implicit mental timeline. Responses were fastest when earlier times were mapped to the left button and later times to the right button (left panel). This pattern of reaction times reversed, however, after brief exposure to mirror-reversed orthography, indicating a reversal of the implicit mental timeline (right panel), and demonstrating a causal role for reading experience in determining its direction. (Reprinted with permission from Ref 35. Copyright 2013 American Psychological Association)

left (*sinister*). Beyond language, people implicitly associate left–right space with positive and negative emotional valence, but not always in the way that linguistic expressions suggest. Rather, associations between valence and horizontal space depend on the way people use their hands to interact with their physical environment.[38–41]

In one series of experiments, participants were asked to decide which of two products to buy, which of two job applicants to hire, or which of two alien creatures looks more honest, intelligent, or attractive. Right- and left-handers tended to respond differently: right-handers tended to prefer the product, person, or creature presented on their right side, but left-handers preferred the one on their left (Figure 4).[38] This pattern persisted even when people made judgments orally, without using their hands to respond. Children as young as 5 years old already make evaluations according to handedness and spatial location, judging animals shown on their dominant side to be nicer and smarter than animals on their nondominant side.[39] In reaction time tasks, right- and left-handers were faster to classify words as positive when responding with their dominant hand, and to classify words as negative when responding with their nondominant hand.[42] Beyond the laboratory, the link between valence and space was found in the speech and gestures of the 2004 and 2008 U.S. presidential candidates during televised debates.[40] In the right-handers (Bush, Kerry), right-hand gestures were more strongly associated with positive-valence speech than left-hand gestures, and left-hand gestures were more strongly associated with negative-valence speech than right-hand gestures; the opposite pattern was found in the left-handers (Obama, McCain).

Overall, these links between valence, and people's dominant and nondominant sides of space cannot be explained by exposure to spatial idioms in language or hand-use conventions in culture (e.g., using the right hand to shake hands or swear an oath). Right-handers' implicit association of 'good' with 'right' is consistent with these conventions, but left-handers' association of 'good' with 'left' goes against them. Where does the mental metaphor Good is Left come from?

Casasanto[38] proposed that people come to associate 'positive' with their dominant side of space because they can usually interact with their physical environment more fluently on this side, using their dominant hand. This proposal follows from the finding that fluent perceptuo-motor interactions with the environment generally lead to more positive feelings, whereas disfluent interactions lead to more negative feelings and evaluations.[43]

To determine whether manual motor fluency drives associations between valence and left–right

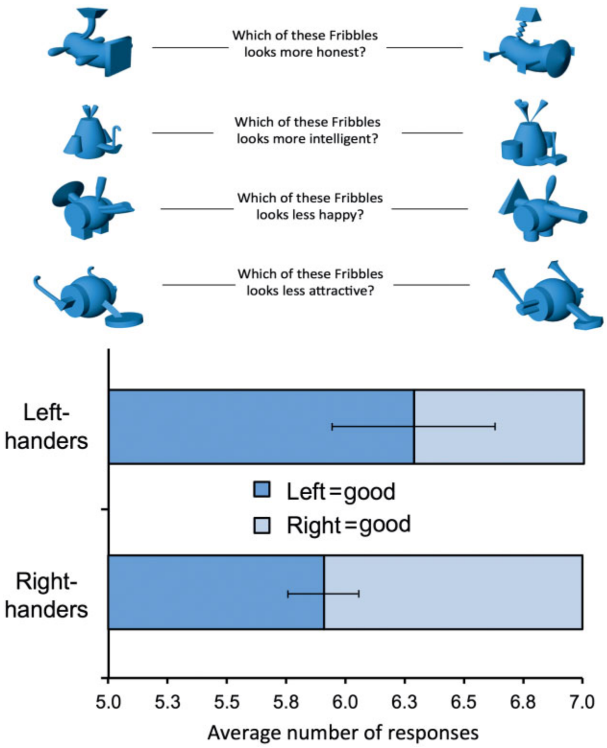

FIGURE 4 | Left–right mapping of emotional valence follows the body, not language. When asked to judge which of two alien creatures looked more (or less) honest, intelligent, happy or attractive, right- and left-handers respond differently. Right-handers tend to prefer creatures on the right of the page, consistent with expressions in language that associate 'good' with 'right'. Left-handers, however, show the opposite preference, associating 'good' with 'left', in spite of linguistic, and cultural conventions that link 'good' with 'right'. (Reprinted with permission from Ref 38. Copyright 2009 American Psychological Association)

space, one study tested how people think about 'good' and 'bad' after their dominant hand had been impaired, reversing the usual asymmetry in motor fluency between their right and left hands.[41] This reversal of motor fluency resulted in a reversal of behavioral responses: natural right-handers whose right hand was impaired permanently by a unilateral stroke, or temporarily by wearing a cumbersome glove on the right hand in the laboratory (Figure 5), tended to associate 'good' with the left side of space, like natural left-handers.

These results demonstrate a causal role for motor experience in determining the relationship between valence and left–right space in people's minds. Good is Right idioms in language enshrine the motor-fluency based preferences of the right-handed majority; left-handers use these verbal idioms explicitly, even though they associate 'good' with 'left' implicitly (Box 1).

BOX 1

ARE MENTAL METAPHORS EMBODIED?

According to theories of embodied cognition knowledge is represented via *simulations* of perceptual, motor and interoceptive states.[44] Crucially, these simulations involve modality-specific areas of the brain (e.g., motor cortex, visual cortex) that support our interactions with the physical environment. Simulations may not be limited to modality-specific brain areas, but the case for embodied simulation collapses if modality-specific brain areas are not involved.[45]

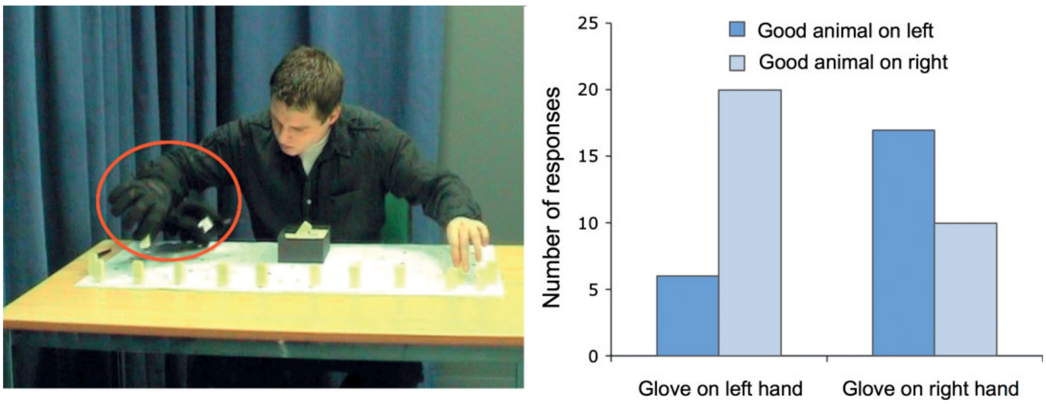

FIGURE 5 | Motor experience influences left–right mapping of valence. Right-handed participants were randomly assigned to wear a bulky ski glove on either their right- or left-hand while performing a bimanual task that required fine motor control (left panel). Participants who wore the glove on their right hand experienced a reversal of their usual manual motor dominance, which resulted in a tendency to associate 'good' with the left side of space, like natural left-handers, demonstrating a causal role for manual motor experience in determining associations between emotional valence and left–right space. (Reprinted with permission from Ref 41. Copyright 2011 Association for Psychological Science)

Should the studies reviewed here be interpreted as evidence that abstract concepts are represented via embodied simulations? This conclusion would be premature.[16,38] In principle, metaphorical representations could comprise embodied simulations, in both source, and target domains. For instance, using the mental metaphor Good is Up could involve activation of motor areas that subserve upward movements or upright postures (source-domain simulations), and activation of striatal areas believed to subserve the experience of positive emotions (target-domain simulations).[38]

Yet, at present, there is little evidence that mental metaphors are embodied in this way. The studies reviewed here provide clear evidence that some abstract concepts are represented, in part, metaphorically. But evidence for metaphor theory is not necessarily evidence for embodiment. Establishing whether the source- or target-domain components of metaphorical representations are embodied in modality-specific simulations would require more direct tests of neural activity than these studies provide; a few more direct tests have been conducted to date, but their results have been mixed.[46–50] It remains an open question whether metaphorical representations of abstract concepts are partly constituted by modality-specific simulations.

CONCLUSION

Linguistic metaphors can provide a window on our spatial conceptualizations of nonspatial domains, including emotional valence, time, and musical pitch. Often the way we talk accurately reflects the way we think, as in the case of mappings between vertical space and valence: typically, 'good' is 'up', and 'bad' is 'down' in both language and thought.[12–17] In a few documented cases, linguistic metaphors determine which mental metaphors people tend to use: whether they conceptualize temporal sequences as horizontal or vertical[19]; duration as length or volume[23]; musical pitch as height or thickness.[27]

Yet, although spatial language is often a good index of spatial thinking, people do not always think the way that they talk. English speakers conceptualize the future as 'ahead' and the past as 'behind,' consistent with linguistic metaphors, but only under some circumstances: primarily, it appears, when they are conceptualizing time from a deictic (viewer-centered) perspective. When they are conceptualizing viewer-independent sequences of events, they tend to activate a mental metaphor linking time with left–right space, which is not reflected in English or any other known spoken language.[29] The left–right timeline typically used to conceptualize temporal sequences is orthogonal to the front–back mapping of time suggested by spoken language, and its direction is determined by cultural practices: not by language, or by experience with the physical environment.

In another dissociation between spatial language and abstract thought, right-handers tend to associate 'good' with 'right' and 'bad' with 'left' but left-handers show the opposite association, in spite of linguistic conventions that have presumably been shaped by the right-handed majority. As such, expressions like 'my right hand man' and 'the right answer' reflect right-handers' implicit mental metaphors, but not left-handers': the Good-is-left mapping in left-handers' minds is the opposite of the mapping suggested by language. Spatial metaphors and idioms in language point to the pervasive use of spatial representations to scaffold our nonspatial thinking. But the specifics of these mappings cannot necessarily be inferred from analyses of language, alone. It remains an empirical question *whether*, *when* and *for whom* metaphorical spatial language reflects people's spatial conceptualizations of abstract domains.

NOTE

[a]Two groups of researchers reported failures to replicate Boroditsky's (2001) study showing different responses to horizontal and vertical spatial primes in English vs. Mandarin speakers. [51, 52] Subsequently, however, the finding that Mandarin speakers make greater use of a vertical axis for temporal sequences than English speakers do has been validated, both by Boroditsky and colleagues [53] and by other researchers [54].

[b]Pitch is not among the domains typically considered to be "abstract," like time, valence or justice: entities that are abstract insomuch as they can never be perceived through the senses. Yet, pitch is more abstract than space insomuch as pitch can only be perceived via one sensory modality, whereas the spatial positions of objects or the spatial relationships among them can often be perceived multimodally, via some combination, or sight, sound, touch and even smell. The *relative* abstractness of pitch compared to space may give rise to people's tendency to represent pitch metaphorically in terms of space.

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