Spatial metaphors and the design of everyday things

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Abstract

People use space to think about a variety of non-spatial concepts like time, number, and emotional valence. These *spatial metaphors* can be used to inform the design of user interfaces, digital and otherwise, in which many of these same concepts are visualized in space. Traditionally, researchers have relied on patterns in language to discover habits of metaphorical thinking. Here we argue that researchers and designers must look beyond language for evidence of spatial metaphors, many of which remain unspoken despite their pervasive effects on people's preferences, memories, and actions. We propose a simple principle for predicting spatial metaphors from the structure of people's experiences, whether those experiences are linguistic, cultural, or bodily. By leveraging the latent metaphorical structure of people's minds, we can design interfaces that help people think.

Significance statement

More than ever, the quality of our experiences is dictated not only by the conditions of the natural world, but also by the decisions of people who design our digital and physical environments. Therefore, these designers have the opportunity, and arguably the responsibility, to create environments (digital and otherwise) that conform to the structure of our unconscious minds. In this regard, space is special because digital interfaces and physical environments are laid out in space, and because people use space to mentally represent many non-spatial concepts. By leveraging the spatial structure of people's minds in the design of everyday things, we can improve the quality of human experiences.

Spatial metaphors and the design of everyday things

Using technology can be hard, but some aspects of digital culture are obvious to users, whether or not the users are technologically savvy. It seems intuitive, for example, that to show approval on social media, users should give a “thumbs up,” not a thumbs down, and that to go “back” to the previous webpage, they should press the arrow pointing left, not the arrow pointing right. Users know this not only because of their experience with technology, but also because of their experience with *space*; starting long before people learn to use computers, and even before they learn to use language, they have a set of implicit spatial associations – associations that can be learned from experience with the physical (i.e. spatial) world (Casasanto, Fotakopoulou, & Boroditsky, 2010; Casasanto & Henetz, 2012; Rugani & de Hevia, 2016; Dolsheid, Hunnius, Casasanto, & Majid 2014). These implicit associations, called *spatial metaphors*, provide a link in people’s minds between space and various abstract, non-spatial concepts like time, quantity, and emotion. Here we discuss how these spatial metaphors, which are latent in the minds of all people, can be leveraged in the design of products, environments, and user interfaces.

What is a spatial metaphor?

In some cases, the spatial metaphors in our minds are reflected in language. For example, when we say *His spirits were soaring* or *She is feeling low*, we are invoking a spatial metaphor linking *up* with positive emotional valence and *down* with negative emotional valence (Lakoff & Johnson, 1980): the same metaphor that gives rise to the conventionalized thumbs up gesture (and the corresponding *Like* button). Dozens of these spatial metaphors are hiding in plain sight throughout language, linking numerous non-spatial conceptual domains with various aspects of space on all three axes, and across dimensions (1-D, 2-D, or 3-D). For example, in English, we use vertical space to talk

about *high* and *low* numbers, lateral space to talk about the *left* and *right* poles of the political spectrum, and sagittal space to talk about moving meetings *forward* or *back* in time. Quantities can be *big* or *small*; vacations can be *long* or *short*; acquaintances can be *distant* or *close*.

According to Conceptual Metaphor Theory (Lakoff & Johnson, 1980), these metaphors in language are more than just figures of speech; rather, they reflect the fact that “most of our ordinary conceptual system is metaphorical in nature” (p. 454). On this proposal, people use mental representations in a *source* domain (like space) to scaffold their representations in a *target* domain (like time, number, or emotional valence), which is typically more abstract. Using the source domain to conceptualize the target domain (e.g. using space to think about time) is hypothesized to support people’s ability to make inferences in the target domain. Indeed, a growing body of experimental evidence supports the proposal that in addition to *talking* metaphorically about abstract domains like time, number, and similarity, people also conceptualize these domains metaphorically – that is, people use space for *thinking* (for a review, see Casasanto & Bottini, 2014a).

Given that spatial metaphors help people think, they provide a valuable starting point for designing user interfaces; users (i.e. people) bring to any interface a set of implicit biases about the way(s) in which many abstract domains should be spatialized. By designing interactions that are congruent with people’s implicit spatial metaphors, designers can leverage the latent structure of users’ minds. By contrast, violating those metaphors (or just ignoring them) results in user experiences that may be unintuitive, unpleasant, or even dangerous. In short, the better we understand the metaphorical structure of people’s minds, the better we are able to design experiences that leverage that structure.

For decades, Lakoff & Johnson’s Conceptual Metaphor Theory (1980) has provided a theoretical basis for the study of metaphorical mental representation, which in turn has influenced the metaphors and “image schemas” that designers have used to inform their work (e.g. Carroll,

Mack, & Kellogg, 1988; Hurtienne & Israel, 2007; Marcus, 1998). However, this seminal theory of metaphorical mental representation is incomplete, producing blind spots in our understanding of the metaphorical structure of people's minds. Specifically, Conceptual Metaphor Theory assumes that:

- i. Spatial metaphors in language reflect how people think
- ii. Spatial metaphors are largely invariant across cultures
- iii. Spatial metaphors are largely invariant across individuals within a culture

As we will illustrate, all three of these assumptions are false (for a detailed discussion, see Casasanto, 2017). First, to fully understand the metaphorical structure of people's minds, we must look beyond language. Although metaphor theorists have typically treated metaphorical language and metaphorical thinking as if they were inseparable, there are many well established dissociations between metaphors in language and in the mind. People's thoughts are structured metaphorically in ways that do not appear in language at all which, in some cases, may contradict patterns in language. Therefore, whereas metaphor theorists have traditionally used a single term (i.e. "conceptual metaphor") to refer to both patterns in language and patterns in thinking, here we will use two terms to make this critical distinction; *linguistic metaphor* refers to metaphorical structures in language and *mental metaphor* refers to metaphorical structures in thinking (Casasanto, 2008).

Below, we will begin by discussing two mental metaphors that have corresponding linguistic metaphors in English (i.e. "Spatial metaphors in language and thought") and highlight their implications for design. We will then turn to mental metaphors that have no corresponding linguistic metaphors (i.e. "Unspoken spatial metaphors") and illustrate how, despite their absence from language, these mental metaphors have potent cognitive and behavioral effects. In subsequent sections, we will discuss how (and why) mental metaphors vary widely across cultures and across individuals, and outline a simple principle for anticipating the particularities of a given person's mental metaphors, whether or not those metaphors are reflected in language.

Spatial metaphors in language and thought.

Good is up. Some spatial metaphors are reflected in language. The *Like* button, mentioned above, reflects an association between vertical space and emotional valence (i.e. positive and negative) that is commonplace in many languages. The GOOD IS UP metaphor also runs deeper than language (e.g. Meyer & Robinson, 2004; Havas, Glenberg, Rinck 2007), and activating this mental metaphor — via interaction with the physical environment — can shape the way we feel, how we act, and what we remember. For example, in one study moving objects upward (i.e. from a low container to a higher container) caused people to recall autobiographical memories with positive emotional valance, whereas moving objects downward caused them to recall more negative memories (Casasanto & Dijkstra, 2010). Beyond partly determining what people recall, this spatial metaphor can also influence how well we learn. In another study, people studied the meanings of “alien” words using flashcards that they placed into an upper or lower bin, according to a rule that was either congruent or incongruent with the GOOD IS UP metaphor (Casasanto & de Bruin, 2019). People who placed the positive words in the upper bin and the negative words in the lower bin (congruent with the GOOD IS UP metaphor) showed a significant improvement in vocabulary learning compared to baseline, whereas those who placed their cards the other way (incongruent with the implicit metaphor) showed a significant decrement. Leveraging people’s spatial metaphor improved learning, and violating it impaired learning.

Good is right. In addition to the GOOD IS UP metaphor, most people¹ also have a GOOD IS RIGHT metaphor linking negative emotions with the left side of space and positive emotions with

¹ Although the GOOD IS RIGHT metaphor obtains for right-handers (approximately 90% of the population), left-handers show the reverse. We discuss this topic in depth below.

the right (Casasanto, 2009). This metaphor has subtle but systematic correlates in English: Being dexterous (i.e. right) is good but being sinister (i.e. left) is bad; likewise, a trusted colleague is a “right-hand man,” whereas a clumsy dancer has “two left feet.” Yet, despite these clues in language, the mental metaphor linking lateral space and valence remained largely unknown to cognitive science even decades after the Lakoff & Johnson wrote about the *vertical* space-valence metaphor linking up with good (1980). The left-right axis was long thought to be “neutral” in valence (Tversky, 2001, p 101; see also Clark, 1973); however a decade of research has now shown that most people implicitly associate good things with the right side of space and bad things with the left (Pitt & Casasanto, 2018).

The lateral space-valence metaphor has widespread effects on the way people perceive, remember, and act. Encountering objects on the right or left side of space influences how people feel about them. When choosing which of two products to buy, which of two job applicants to hire, which of two alien creatures looks more honest (Casasanto, 2009), or which person to date or to befriend (Zhao et al., 2016), lateral space matters. Most people are biased to choose the person, product, or creature they find on the right of the page or the computer screen. This spatial metaphor can also color our memories; when asked to remember the location of fictitious events, most people are biased to err to the right (and upwards) for positive events and to the left (and downwards) for negative events (Brunyé, Gardony, Mahoney, & Taylor, 2012). When asked to arrange emotional faces on a left-right continuum, most people are biased to place the happy faces on the left and the unhappy faces on the right (Freddi et al., 2016).

The GOOD IS RIGHT metaphor shapes our minds in some surprising ways. Notably, this mental metaphor appears to have unintended effects on language via one of the most common user interfaces in the industrialized world: the QWERTY computer keyboard. On a standard QWERTY keyboard, some of the letters are typed on the left side with the left hand (Figure 1, blue keys) and

some are typed on the right side with the right hand (Figure 1, red keys). Given that most people associate right with good and left with bad, the layout of the keys could influence the emotional valence of the letters, and therefore of any typed word: a relationship between the meanings of words and the way they are typed now known as the “QWERTY effect” (Jasmin & Casasanto, 2012). In a first test of this effect, the emotional valence of words was predicted in part by the way they were typed on the QWERTY keyboards used to produce US English, Dutch, Spanish, and large corpus of “alien words” rated by English speakers. Words (and pseudowords) with more right-side letters were found to be, on average, more positive in valence. This effect was later extended to Portuguese and German words, and found for ratings of single letters, per se: Letters farther to the right on the keyboard were rated to be more positive on average (Casasanto Jasmin, Brookshire, & Gijssels, 2014). Not only does QWERTY subtly shape the meanings of ordinary words, it also appears to influence the names parents choose for their children. Since the widespread adoption of the QWERTY keyboard, names with more right-side letters have dramatically increased in popularity while names with more left-side letters have decreased in popularity in the US. Likewise, names invented since the adoption of QWERTY have a decidedly right-sided slant, comprising more right-side letters compared to names in use before QWERTY (Casasanto, et al., 2014). The QWERTY effect illustrates one way in which the interfaces we design to produce language can *shape* language, in return, via the spatial metaphors in our minds.

Figure 1. On the QWERTY keyboard, some letters are typed with the left hand (blue) and some are typed with the right hand (red). The left-right distribution of letters on this interface influences the meaning of words as predicted by the GOOD IS RIGHT metaphor.

Unspoken spatial metaphors.

Whereas some mental metaphors are evident in language (e.g., GOOD IS UP, GOOD IS RIGHT), other mental metaphors are entirely absent from language. One such metaphor is revealed by a simple exercise: If asked how best to arrange the words “today,” “tomorrow,” and “yesterday” in left-right space, many readers will find the best arrangement to be obvious:

yesterday today tomorrow

The intuition to put earlier events on the left and later events on the right is a product of our lateral *mental timeline*, a mental metaphor in which temporal succession is mapped onto left-right space (Tversky, Kugelmass, & Winter, 1991). People have similarly strong intuitions about the relationship between lateral space and numbers; thanks to an implicit *mental number line*, people associate smaller numbers with the left and larger numbers with the right (Dehaene, Bossini, & Giraux, 1993). These space-time and space-number metaphors are not reflected in language; numbers can be “high” or “low” but they are not “left” or “right”; events in time can be moved “forward” or “back” but not “leftward” or “rightward.”

Yet, despite their absence from language, these lateral space-number and space-time associations have robust effects on people’s behavior. For example, in tests of space-number associations, people spontaneously generate larger numbers when turning their head to the right and smaller numbers when turning to the left (Loetscher, Schwarz, Schubiger, & Brugger, (2008). Likewise, seeing smaller numbers causes people to shift their attention to the left, and seeing larger numbers shifts attention to the right (Fischer, Castel, Dodd & Pratt, 2003; Loetscher, Bockisch & Brugger, 2008). In tests of space-time associations, people spontaneously gesture to the left when

describing earlier events in time and to the right for later events (Casasanto & Jasmin, 2012); When recalling items from a memorized sequence, people's gaze shifts leftward when recalling earlier items and shifts rightward when recalling later items (Rinaldi et al., 2015).

Although unspoken, the specific space-time and space-number mappings just described are intuitive enough that they are incorporated into much of the built environment, digital and otherwise. The mental number line is reflected in charts and graphs, in which smaller numbers appear to the left of larger numbers, and in a variety of common interfaces, ranging from the number keys at the top of your computer keyboard to the dial on your car radio: to get from 98.7 FM to 101.5 FM, you have to move to the right. The mental timeline has an especially pervasive influence. Beyond constraining the layout of printed timelines and wall calendars, the mental timeline predicts the arrangement of digital interfaces that range from the Start menu (on the left of a computer screen) to the Play icon on any media player (pointing right) and the Back button built into your smartphone (pointing left). This space-time mapping shows up in the analogue environment as well. For example, on store shelves in the US, shampoo bottles tend to be placed to the left of conditioner bottles, reflecting the order in which customers typically use these products (Figure 2A).

If the left-to-right mappings of time and number were common to all users, then designers could rely on their intuitions to develop interfaces that would be congenial to all users. However, the mental timeline and mental number line, like many other mental metaphors, are not universal. Rather, the specifics of people's implicit spatial metaphors (i.e. their spatial directions and dimensions) vary across individuals and groups, as we discuss below. For this reason, following one's intuitions about spatial metaphors can be misleading, causing designers to rely on metaphors that may be appropriate for their own demographic but may be at odds with the spatial metaphors in many other users' minds.

Cultural variation in spatial metaphors.

However natural it may seem for time to flow to the right and for numbers to increase to the right, these space-time and space-number mappings are culture-specific. In some non-Western cultures, the mental timeline and/or mental number line go from right to left (e.g. Fuhrman & Boroditsky, 2010; Shaki, Fischer, & Petrusic, 2009; Tversky et al., 1991). For people in those cultures, placing tomorrow to the right of today might seem obviously *wrong* – tomorrow belongs on the left! The culture-specific direction of the mental timeline is even reflected in the typical arrangement of consumer products; whereas shampoo bottles tend to be found on the left of conditioner bottles in the US (Figure 2A), these products tend to be arranged in the opposite way on store shelves in Israel, consistent with Israelis' right-to-left mental timelines (Figure 2B). Like the mental timeline, the mental number line also differs in direction across cultures; people in some cultures implicitly associate larger numbers with the *left* and smaller numbers with the *right*, contrary to the space-number mapping typical in Westerners (Shaki et al., 2009). As a consequence, many of the design elements that cater to Westerners' implicit space-time and space-number metaphors are completely backwards for people in these other cultures, producing a potential conflict between the way these domains are spatialized in their minds and the way they are spatialized in the built environment.²

² In an effort to minimize such conflicts in spatial metaphors, a subset of user interfaces are designed to support both right-to-left and left-to-right layouts. For example, when an Israeli opens Microsoft Excel, the first cell that is highlighted is the upper right cell, not the upper left. But these right-to-left layouts are rare and often incomplete, leaving entire populations to live with the difficulty that comes from mixing metaphors.

Figure 2. Everyday objects tend to be arranged in space according to the mental timeline, which varies in direction across cultures. (A) Typical arrangement of shampoo and conditioner bottles in the US, consistent with a left-to-right mental timeline. (B) Typical arrangement of shampoo and conditioner bottles in Israel, consistent with a right-to-left mental timeline.

This conflict can have culture-specific effects on learning and memory. For example, when asked to memorize arbitrary pairings of letters and shapes, English-speakers learned the pairings better when they were presented from left to right, congruent with the direction of their mental timelines, than when they were presented in the other direction. Hebrew-speakers also showed a culture-specific effect of direction; whereas right-to-left presentation impaired learning in English-speakers, it improved learning in Hebrew-speakers (McCrink & Shaki, 2016). Such findings illustrate why it is important that designers do not simply rely on their own intuitions even when laying out a simple user interface; what is natural and helpful to one group of users can be unnatural and detrimental to others.

Whereas the mental timeline and mental number line differ in spatial direction (e.g. rightward, leftward), other mental metaphors differ in their spatial dimensions (e.g. length, thickness, size). For example, to describe musical pitches, speakers of many languages including as English and Dutch use unidimensional space; “high” pitches are associated with higher points in space and “low” pitches are with lower points in space. By contrast, in languages like Farsi, pitches are described as “thin” or “thick.” Speakers of “height languages” and “thickness languages” conceptualize pitch accordingly, as shown by non-linguistic tests of pitch reproduction. Whereas

English and Dutch speakers implicitly associate high and low pitches with high and low locations in space, Farsi speakers implicitly associate high pitches with thinner objects and low pitches with thicker objects (Dolscheid, Shayan, Majid, & Casasanto, 2013). This thickness-pitch mapping differs from the height-pitch mapping not in direction, but in the spatial dimension that serves as source domain (i.e., unidimensional height v. multidimensional thickness).

Similarly, different language groups use different spatial dimensions to conceptualize temporal duration. English-speakers conceptualize temporal duration using spatial *length*, as reflected in their linguistic metaphors for duration (e.g. a “short” or “long” vacation; Casasanto & Boroditsky, 2008). By contrast, Greek-speakers conceptualize duration in multi-dimensional space – that is, as *amount* or *size*, not length (Casasanto, 2010). For Greek speakers, a “long” night is “big” in time, and “short” night is “small,” a pattern found both in their linguistic metaphors and in their non-linguistic mental metaphors for duration.

In sum, mental metaphors differ across cultures in a variety of ways; the mental timeline and mental number line differ in which *direction* they go whereas the space-pitch and space-time metaphors described above differ in which spatial *dimensions* they use (i.e. height vs. thickness for pitch, length vs. size for duration). Designing for these culture-specific mental metaphors cannot be accomplished by simple translation (Marcus, 2000). Even if an interface uses the appropriate linguistic metaphors (e.g. “thick pitches”) and the right directionality (e.g. left-to-right), it can still violate its users’ mental metaphors by using the wrong set of spatial dimensions. For example, at the bottom of every YouTube video is a red line that grows rightward as the video plays, which conforms to English-speakers’ conceptions of time as (a) linear and (b) rightward. For Arabic-speaking users, this user interface (UI) element could be flipped to accommodate the direction of their mental timeline (which progresses from right to left). However, no simple transformation of

that line could accommodate Greek-speakers' preferred multi-dimensional conception of duration (i.e. as spatial volume); lines simply do not use the right kind of space.

Individual variation in spatial metaphors.

Mental metaphors not only vary across cultures; some also vary across individuals within a culture. The prime example of such variation is found in the lateral space-valence metaphor introduced above. The RIGHT IS GOOD mapping is found selectively in *right-handed* people. Left-handers show exactly the opposite set of associations between emotional valence and lateral space: an implicit GOOD IS LEFT mapping. In this way, lateral space-valence metaphors are *body-specific*; people with systematically different bodily experiences (e.g. as determined by their handedness) develop systematically different mental metaphors as a consequence (Casasanto, 2009; Casasanto & Chrysikou, 2011).

Whereas right-handers prefer objects on the right and disprefer objects on the left, the opposite is true for left-handers who, on average, prefer people, products, and pictures they encounter on the left side of a page or a screen (Casasanto, 2014, for a review). Likewise, whereas right-handers' memories for the locations of positive events are biased to the right, left-handers' memories for the same events are biased to the left (Brunyé et al., 2011). Beyond the laboratory, the body-specific space-valence mapping is evident in the spontaneous gestures people produce while they speak. In the final debates of the 2004 and 2008 U.S. presidential elections, positive speech was more strongly associated with right-hand gestures and negative speech with left-hand gestures in the two right-handed candidates (Bush and Kerry), but the opposite pattern of gestures was found in the two left-handed candidates (McCain and Obama; Casasanto & Jasmin, 2010). The association of good and bad with one's dominant and non-dominant sides of space is found in children as young

as 5 years old (Casasanto & Henetz, 2012), suggesting that this implicit mental metaphor may be relevant to the design of educational materials and practices.

The left-right mapping of emotional valence has broad implications for user interfaces since many UIs require people to choose among options arrayed in space. In voting booths, for example, people typically encounter arrays of options, either as levers on a panel or as names on a printed ballot. As these options are often arranged in columns, some candidate's names are found above or to the right of other candidate's names. It has long been recognized that being listed at the top of a ballot confers a substantial advantage on candidates (Miller & Krosnick, 1998), but the reason for this advantage has remained unclear: In principle, this advantage could be due to temporal and/or numerical primacy, or to ballot-specific conventions such as listing the incumbent first. One study, however, suggests implicit spatial metaphors are at least partly responsible for ballot-order effects. In a stratified national sample, Americans were asked to vote in a simulated election, responding on ballots with candidates' names arranged either vertically (i.e. above and below each other) or laterally (i.e. to the left and right of each other; Kim, Krosnick, & Casasanto, 2015). In addition to showing a trend toward the typical top-of-ballot advantage, the results showed that the left-right positions of candidates' names affected how many votes they received. Left-handers were 15 percentage points more likely than right-handers to select the candidate whose name was on the left of the ballot, a body-specific effect of people's implicit space-valence metaphors. Such findings highlight a challenge for designers: Incidental spatial relationships in user interfaces can have unintended (and potentially serious) consequences, systematically biasing some users toward one set of choices and other users toward the alternative choices.

Fortunately, as researchers learn more about mental metaphors, designers can be better equipped to anticipate many of the spatial biases that people exhibit. With this knowledge, designers can not only mitigate the unintended effects of those biases (e.g. by randomizing the location of

candidate names on ballots, a practice that has not been universally adopted across US voting districts), but can also use implicit spatial metaphors strategically to optimize user experience. For example, when eliciting ratings from users of a website, a restaurant, or an airport bathroom, companies often use a rating scale consisting of smiley and frowny faces arranged in lateral space (see Figure 3A). In many cases, these faces are presented with the happiest faces on the left and the saddest faces on the right, an arrangement that is directly in conflict with the GOOD IS RIGHT mapping held by 90% of the population (i.e. right-handed people).³ As a result, for most people, the most common interface for rating one's experience is backward, presenting happy faces on the negative side of space and sad faces on the positive side. When the faces are presented in the other direction, as they are in some cases (Figure 3B), this arrangement is consistent with the GOOD IS RIGHT mapping of most users but is inconsistent with the GOOD IS LEFT mapping of a substantial minority: left-handed users (e.g., over 30 million Americans). Whichever way the faces are arrayed in left-right space, such interfaces contradict the lateral space-valence metaphor of some subset of users, and this conflict likely introduces a source of noise into ratings data; some of the most satisfied users may inadvertently choose the saddest face (because it is located on their "good" side) and some of the least satisfied users may choose the happiest face (located on their "bad" side).

³ On what basis are these faces arranged in Figure 3A, if not according to a GOOD IS RIGHT mapping? Presenting happier faces on the left and sadder faces in the right likely reflects the order in which the words "happy" and "sad" are typically spoken and written; people are more likely to say "happy or sad" than "sad or happy."

Figure 3. The left-right spatialization of emotions on rating scales often violates the GOOD IS RIGHT mapping characteristic of most people (i.e. right-handers; A). Interfaces that are congruent with that mapping (B), are necessarily incongruent with the GOOD IS LEFT mapping of left-handers. Vertical rating scales (C) leverage the universal GOOD IS UP mapping shared by all users.

How can designers accommodate such individual variation in mental metaphors? In the case of rating scales, no set of laterally-presented smiley faces could be congruent with the lateral space-valence mappings of both left-handed and right-handed users, since their mappings go in opposite directions. Rather, the solution may simply be to orient the smiley faces in vertical space, as some interfaces already do (Figure 3C); given that the GOOD IS UP metaphor appears to be universal (and does not vary with handedness; Casasanto, 2009) it provides a single arrangement of smiley and frowny faces that is congruent with a space-valence metaphor that is presumably found in all users' minds. Although there is a simple design solution in the case of rating scales, many other UI elements do not have a one-size-fits-all solution. Rather, in order to fully leverage the latent structure of people's minds, an interface must be *language-specific*, *culture-specific*, or *body-specific* — like the mental metaphors of its users. In the next section, we discuss a principled way to predict how mental metaphors vary across individuals and groups.

How to anticipate people's spatial metaphors.

Spatial metaphors can be spoken or unspoken, and they can vary widely across cultures and individuals. Nevertheless, researchers and designers alike can make clear predictions about the structure of mental metaphors (i.e. source-target mappings in the mind) using the CORrelations in Experience (CORE) principle (Pitt & Casasanto, 2019). According to the CORE principle, the way source domains (like space) and a target domains (like musical pitch or emotional valence) are mapped in the mind is determined by the way those domains are correlated in a person's experience. When applied to spatial metaphors (i.e. mental metaphors in which the source domain is space), the principle simplifies to: Abstract domains are spatialized in the mind according to the way they are spatialized in experience. This simple principle allows us to use the structure of people's experience to make predictions about the structure of their mental metaphors. The CORE principle can explain all of the mental metaphors discussed above and why they vary in the ways they do. Three examples show how mental metaphors are predictable on the basis of people's cultural, linguistic, and bodily practices.

Predicting space-time metaphors from cultural practices. The direction of the mental timeline has been attributed to the direction of reading and writing across cultures (e.g. Tversky et al., 1991; Fuhrman & Boroditsky, 2010; Casasanto & Bottini, 2014b) but why would reading experience shape the way people think about time? When reading a line of English text, the reader's gaze starts on the left side of the page at an earlier time and ends on the right side of the page at a later time. This experience provides a correlation between space and time in the act of reading, and this space-time correlation is reversed when reading Hebrew or Arabic text (which is written from right to left). Therefore, according to the CORE principle, reading text left-to-right should yield a mental timeline

that progresses rightward, and reading text right-to-left should yield a mental timeline that progresses leftward, consistent with the variation in mental timelines observed across cultures.

The relationship between the direction of reading and writing and the direction of the mental timeline is more than just correlational. In a series of training studies (Casasanto & Bottini, 2014b; Pitt & Casasanto, 2019), participants read the same text either normally (left-to-right) or mirror-reversed (right-to-left) and then performed a test of their implicit mental timelines. This laboratory manipulation tests whether reading experience can cause changes to the mental timeline, holding other variables constant. And it can; just a few minutes of reading mirror-reversed text is enough to weaken or even reverse people's normal mental timelines.

Predicting space-pitch metaphors from linguistic practices. Why do different cultures have different mental metaphors for musical pitch? In this case, the answer is found in language. When people describe pitches as “high” or “low” this metaphor in language can cause the listener to activate mental representations of vertical space – concepts of literal high or low spatial position. Likewise, when people describe pitches as “thick” or “thin,” as Farsi speakers do, this metaphor in language can cause the listener to activate mental representations of spatial thickness. These different linguistic experiences provide different correlations between representations of pitch and space. Given that these different linguistic metaphors provide different correlations in experience, CORE predicts the difference in mental metaphors observed in Dutch- and Farsi-speakers discussed above (Dolscheid et al., 2013). Beyond this correlation, CORE also predicts that using a new linguistic metaphor for pitch should cause people to adopt a different mental metaphor. Indeed, training speakers of a “height” language to describe pitches in terms of thickness caused them to conceptualize pitch using representations of thickness, like speakers of a “thickness” language (Dolscheid et al., 2013).

Predicting space-valence metaphors from bodily practices. Why do right-handers associate right with positive emotions and left with negative emotions, and why do these associations reverse in left-handers? Although the form of the human body is largely symmetrical across left-right space, the way we use our bodies is lopsided; most people have a dominant hand with which they can interact with the world more easily than the other. Right-handers can interact with their environment more fluently on the right side of space, whereas left-handers experience more fluent body-world interactions on the left. A large literature has established links between fluency and positive evaluations: People tend to like things better when they experience them more fluently (Reber, Schwartz, & Winkielman, 2004). The asymmetry in manual fluency across people's two hands provides a correlation in bodily experience between side of space and emotional valence; the dominant-hand side is fluent (i.e., positive), the non-dominant side is relatively disfluent (i.e., negative). On the basis of this bodily experience, the CORE principle predicts the body-specific space-valence metaphors that are observed: GOOD IS RIGHT for right-handers and GOOD IS LEFT for left-handers (Casasanto, 2009; Casasanto & Chrysikou, 2011). If this body-specific pattern results from differences in manual fluency (and not to differences in brain lateralization, for example), then changing people's manual fluency should cause changes to their lateral space-valence mappings. Consistent with CORE, transiently impairing the manual fluency of people's dominant hand (by putting a bulky ski glove on it) reversed their normal space-valence mappings (Casasanto & Chrysikou, 2011).

How designers change minds (whether or not they mean to). The findings summarized in the previous section offer two high-level insights for design. First, mental metaphors vary across individuals and groups and these variations can be predicted using the CORE principle, on the basis of cultural, linguistic, and bodily practices. Second, the spatial metaphors that structure our minds

can be changed by new patterns of experience. Changing the relevant aspects of people's experience in the laboratory (e.g. by manipulating the way they read text, describe pitches, or use their hands), even just for a few minutes, is enough to change their mental metaphors, at least transiently. Given that mental metaphors can be changed by experience, designers who determine the structure people's everyday experiences inadvertently become stewards of their mental metaphors. Any experience that spatializes an abstract idea has the potential either to reinforce the implicit spatial metaphor that structures that idea *or to systematically change it*. Designers, therefore, should be aware of the possibility not only to leverage, but also to alter, the metaphorical structure of users' minds.

Conclusions

Many of our most basic concepts are structured by spatial metaphors, including concepts of time, number, musical pitch, and emotional valence. Whether or not these metaphors are found in language, they have pervasive and sometimes profound effects on the way people think, feel, and act. Spatial metaphors are so pervasive that nearly any user interface will inevitably engage with at least one of them, whether intentionally or unintentionally. (After all, spatializing non-spatial ideas is what graphical user interfaces do!) The goal of user experience designers should be not only to make interfaces intuitive and inclusive (Hurtienne, Weber, & Blessing, 2008), but also to make user experiences that help people think, feel, and act. User experiences that conform to people's mental metaphors can improve learning and increase positive evaluations, whereas experiences that violate their mental metaphors can have the opposite effects.

The biggest challenge may be to design interfaces that accommodate (or even better, leverage) the multi-dimensional variation in people's mental metaphors. How can designers anticipate the mental metaphors of their users when those metaphors vary within and across cultures, and are often nowhere to be found in language? According to the Correlations in

Experience principle, the answer lies in people's everyday experiences, whether those experiences are cultural, linguistic, or bodily. CORE provides a way for researchers and designers, alike, to make principled predictions about the structure of people's minds from the structure of their experiences, and gives the people who determine the structure of our physical and digital environments a comprehensive, user-centered set of metaphors to design by.

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