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# When Gesture Becomes Analogy

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**Abstract**

Analogy researchers do not often examine gesture, and gesture researchers do not often borrow ideas from the study of analogy. One borrowable idea from the world of analogy is the importance of distinguishing between attributes and relations. Gentner (1983, 1988) observed that some metaphors highlight attributes and others highlight relations, and called the latter *analogies*. Mirroring this logic, we observe that some metaphoric gestures represent attributes and others represent relations, and propose to call the latter *analogical gestures*. We provide examples of such analogical gestures and show how they relate to the categories of iconic and metaphoric gestures described previously. Analogical gestures represent different types of relations and different degrees of relational complexity, and sometimes cohere into larger analogical models. Treating analogical gestures as a distinct phenomenon prompts new questions and predictions, and illustrates one way that the study of gesture and the study of analogy can be mutually informative.

*Keywords:* Gesture; Analogy; Metaphor; Iconicity; Relational reasoning; Abstract reasoning

## 1. Eggs and omelets, attributes and relations

There are a number of differences between an egg and an omelet. One is raw, the other cooked. One is small and oval, the other flat and round. If one wanted to represent such features in gesture, it would be easy enough. For instance, you could show the small, contained shape of the egg by holding up a closed fist. For comparison, you could

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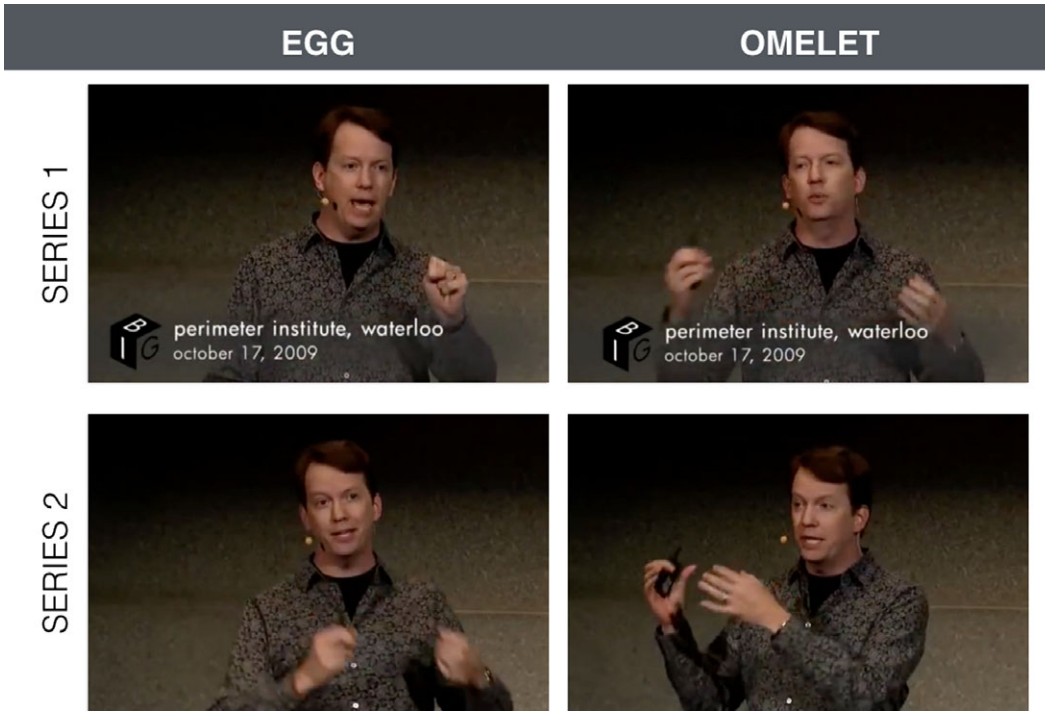


Fig. 1. Four gestures produced in the course of repeated reference to an "egg" and an "omelet." In the first series (top), the speaker produces iconic gestures that represent concrete aspects of the egg and the omelet. In the second series (bottom), his gestures do not represent attributes, but instead relate these two entities in time, with the egg on his left (earlier) and the omelet on his right (later). The second series constitutes a simple analogical model.

then model the shape of the omelet with two hands. Indeed, the cosmologist Sean Carroll produces gestures very much like this at the start of a 2009 lecture on the origins of the universe. They occur as he says: "We can take an egg and turn it into an omelet." These are what gesture researchers call *iconic gestures*—gestures in which handshapes and movements represent visuospatial features of the world.

Immediately afterward, Carroll produces another pair of gestures as he continues: "But it's very hard to take an omelet and turn it back into an egg." In this second series, the gestures have a more abstract character. As he says "omelet," he twists to his right and brings both hands firmly down on the right side of his gesture space; as he says "egg," he brings his hands back across his body and then down on the left side of his gesture space. This time nothing about his handshapes distinguishes the "egg" from the "omelet"; indeed, nothing about the gestures differs except for the locations where the hands are placed in space. Whereas in the first series Carroll's gestures represent *attributes* of the egg and the omelet—in particular, their size and shape—in the second series, he highlights a *relation* between those objects (Fig. 1). The key relation is a temporal one: Thanks to the irreversibility of time, the omelet must happen *after* the egg. Carroll conveys this relation by placing his

gestures along a left–right axis representing time: The space to his left (where the gesture for *egg* is produced) represents an earlier time than the space to his right (where the gesture for *omelet* is produced). For Carroll's purposes, the egg and the omelet are interesting because they illustrate time's arrow, a bedrock principle of cosmic order. For our purposes, what is interesting is that Carroll's second gesture series, in which attributes are abstracted away and relations take center stage, has all the features of an analogy.

The importance of the distinction between attributes and relations will be obvious to those familiar with the wide-ranging work of Dedre Gentner and her collaborators. Over several decades of research, Gentner has shown how this distinction can illuminate some of the most important topics in cognitive science: how figurative language is processed, the relationship between language and thought, how children learn, the history of scientific reasoning, the difference between human and animal intelligence, and many more. Research by other scholars, too, has explored the many ways in which higher-order cognition depends on relational reasoning (Doumas, Hummel, & Sandhofer, 2008; Goldstone, Medin, & Gentner, 1990; Hofstadter & Sander, 2013; Holyoak & Thagard, 1995; Markman, 1997). Yet in the world of gesture studies, this powerful distinction has not yet taken root. Our aim in this paper is to show that the contrast between attributes and relations—as well as related analytic tools from Gentner's structure mapping framework—can cast light on gesture and cognition. In particular, these tools call attention to different classes of gesture that have previously been lumped together, but which—given the importance of relational structure in human thinking—should not be. Thus, the study of analogy can inform research on gesture, opening up a host of new questions (see also Cooperrider, Gentner, & Goldin-Meadow, 2016). Our bet is that, in turn, the study of gesture can inform research on analogy, providing a new arena within which to investigate how analogical thinking is manifest in everyday behavior.

We are certainly not the first to try to bring these two areas into contact. In recent years, several researchers have begun to use structure mapping (and other conceptual mapping approaches) to understand meaningful body movements. For example, Taub (2001) has analyzed iconicity in American Sign Language as involving a structured mapping between a mental representation (e.g., of a tree) and a certain configuration of the body (e.g., a forearm held vertical, with the fingers spread). Several researchers since have used similar approaches to explain features of sign language metaphors (e.g., Meir, 2010) and to account for findings about sign language processing and learning (e.g., Emmorey, 2014). The iconicity identified in sign language is also ubiquitous in the spontaneous gestures that speakers produce, and some have begun to use conceptual mapping frameworks to analyze these gestures (e.g., Clark, 2016; Parrill & Sweetser, 2004). Any gesture that depicts what it refers to can be analyzed through the lens of structure mapping. For instance, the egg-as-fist gesture involves a mapping between a *mental representation* of an egg, with features of roundness, smallness, and so on, and a *bodily representation* of an egg, with the fist forming a small round shape. As described in structure mapping theory, the mappings in this example are selective (Gentner, 1983). The forearm protruding from the fist has no counterpart in the mental representation of an egg, and the yolk does not have any counterpart in the bodily representation. Structure

mapping approaches may indeed prove to be a powerful lens through which to analyze iconic gestures, and it may generate predictions that would not have otherwise been made. Our focus is not on these relatively concrete gestures, however, but on what are commonly called "metaphoric gestures." In iconic gestures, the visuospatial properties of the gesture directly represent the visuospatial properties of a concrete referent, be it an object, action, or spatial relationship. In so-called metaphoric gestures, visuospatial properties of gesture are used to represent abstract ideas and relationships, concepts that have no inherent visuospatial properties.[1] In Section 2, we elaborate on a key difference between different kinds of metaphoric gestures, one directly inspired by one of Gentner's early observations about figurative language.

## 2. Some metaphoric gestures are analogies

For as long as researchers have studied gesture, they have noted that gestures often render abstract thoughts into visible form. The Roman rhetorician Quintillian, writing in antiquity, and the German psychologist Wilhelm Wundt, writing in the 19th century, both comment on such gestures (discussed in Kendon, 2004). David Efron (1972), who made systematic observations of gesture without the benefit of video, separated out a class of what he called "logicotopographic gestures," which represent a "diagram of the ideational structure of discourse" (Kendon, 2004, p. 93). More recently, in the influential typology put forward by McNeill (1992), "metaphoric gestures" are considered a distinct type in which "abstract content is given imagery in the form of objects, space, movement, and the like" (p. 145). This is a sprawling, colorful, and ubiquitous category. Indeed, McNeill comments that, in certain kinds of discourse such as conversations and lectures, metaphorics are "among the most frequent of all gestures" (p. 163). Given the diversity of this class, it is natural to ask whether more fine-grained distinctions might be possible—and, more important—*useful*. That is, are there distinctions that might matter for the kinds of questions gesture researchers—and cognitive scientists generally—care about?

Here, we draw an analogy. The state of research on *gestural metaphors* today might be likened to the state of research on *verbal metaphors* before Gentner (1983). For a long time, verbal metaphor was an undifferentiated category, and "metaphor" and "analogy" were often treated as rough synonyms (as they often still are today in informal language). Gentner and colleagues have proposed that both metaphor and analogy are non-literal comparisons that relate a target concept to a base concept; however, analogy is a special case, one in which the two concepts share relations but do not necessarily share attributes (Gentner, 1983, 1988; Gentner & Markman, 1997). Consider two figurative expressions, "The sun was a grapefruit" and "That job is a jail." In the first, the target (sun) shares with the base (grapefruit) salient *attributes*—for example, both are spherical. In contrast, in "That job is a jail," the target (job) shares no salient attributes with the base (jail), but it does share salient relations—for example, both are confining. The "job as jail" figurative expression is a special case of non-literal comparison in which relations are privileged over attributes, and it is this type that Gentner labels *analogy*.

Continuing with our own analogy, we might ask: If there is a special case of non-literal comparison in which relations are paramount, might there also be a special case of abstract gesture in which relations are paramount? Yes, there is—and we call this special case *analogical gesture*. The critical feature for this distinction is what the gesture represents.[2] A series of minimally contrasting examples will help clarify what sets analogical gestures apart from other metaphoric gestures and from iconic gestures (see Table 1).

Again, iconic gestures use space (base representation) to represent concrete spatial attributes and relations of whatever is being described (target representation). An example of an *attribute iconic* would be a person using two C-shaped hands, spread apart, to represent the large size of a beach ball. A *relational iconic* might represent the spatial relation between two objects, for example, using two flat palms, one on top of the other, to show that one book is above another on a shelf. Metaphoric gestures also use space (base representation) to represent attributes and relations of whatever is being described (target representation), but those attributes and relations are not inherently spatial. A case of an *attribute metaphoric* would be a speaker using two C-shaped hands, spread apart, to convey the importance of an idea by representing it as large in size. A *relational metaphoric*—the subtype we are calling an "analogical gesture"—might be a speaker using two flat palms, one on top of the other, to show that one idea is more important than another by representing its placement on a vertical scale of importance, with one idea being higher (i.e., more important) than the other. In the relational iconic example, the hands show an actual spatial relation—vertical position on a shelf. In the corresponding analogical gesture example, the hands represent a relation that is not inherently spatial—relative importance—as a spatial relation.

Our focus in what follows will be on analogical gestures—metaphoric gestures that foreground relations. But, first, it is worth saying a bit more about metaphoric gestures that highlight attributes, which have figured prominently in prior treatments of abstract gesture. A common case of an attribute metaphoric involves representing an ethereal abstraction as though it had some of the properties of an actual, physical object. Mittelberg (2008) describes several such gestures produced in introductory linguistics classes. One professor refers to "grammar" while putting both hands out, palms facing each other,

Table 1
Subtypes of iconic and metaphoric gestures

| | Iconic Gestures (space represents space) | Metaphoric Gestures (space represents non-space) |
|---|---|---|
| Attributes represented | *attribute iconics*<br>example: two-handed gesture representing the size of an entity | *attribute metaphorics*<br>example: two-handed gesture representing the size of an idea to convey its importance |
| Relations represented | *relational iconics*<br>example: two-handed gesture representing one entity above another in space | *relational metaphorics* (= analogical gestures)<br>example: two-handed gesture representing one entity above another to convey its relative importance |

as though holding a small box (Mittelberg, 2008, p. 126). Grammar is thus treated as an object of a certain size and shape. A different lecturer refers to the idea of a "main verb" while extending a cupped hand, as though holding the verb out for inspection (p. 129). Grammars and verbs do not, of course, have any physical form—they are intrinsically abstract ideas that become, in McNeill's terms, "entified" in gesture (McNeill, 1992, p. 154). Other attested examples of metaphoric gestures in which attributes are central include gestures showing the "size" of a duration (e.g., Cooperrider & Núñez, 2009) or a number (e.g., Winter, Perlman, & Matlock, 2013), as though it were the size of an object. Another example is the precision grip gestures produced with words like "specifically" or "especially," which recast the notion of specificity in terms of small size (Kendon, 2004; Lempert, 2011).

Now that we have situated analogical gestures within a general framework, we can consider some complexities. A first complexity is that analogical gestures do not necessarily represent relations between abstract entities. Our opening example involved an egg and an omelet. Unlike *grammar* or other ethereal ideas, eggs and omelets are concrete—you can pick them up, drop them on the floor, or eat them. What *is* abstract is the relation between the egg and omelet—that the egg is necessarily the precursor of the omelet. Thus, analogical gestures use spatial relations to represent non-spatial relations between entities or ideas, no matter whether those entities are themselves abstract or concrete. A second complexity is that analogical gestures can represent both attributes and relations at the same time—it is not either–or, much as in the case of verbal metaphors that highlight both common attributes and common relations (Gentner, 1988). This would be the case if, for instance, Carroll had depicted the shape features of the egg and the omelet while *also* using space to represent the temporal relation between them. Gestures that represent actions—whether iconic or metaphoric—commonly represent both relations (who acts on whom) and attributes (what the action was like). A third complexity is that, much as the distinction between literal and non-literal similarity is a continuum in structure mapping theory (e.g., Gentner & Markman, 1997), the distinction between iconic and metaphoric gestures may also be thought of as a continuum. Intermediate cases exist in which a gesture dimly echoes an actual spatial relationship, but schematizes it to degree that makes it quite abstract. For example, if a speaker contrasts the United States and Australia by gesturally placing the United States on her left and Australia on her right, this placement echoes an actual relationship on an east–west axis, but also schematizes the relationship, in that the countries are at different latitudes.

To our knowledge, analogical gestures have not been treated as a separate class before. Our first task is thus to characterize this new class in more detail: In Section 3, we consider how analogical gestures vary in the type and complexity of the relational structure involved; in Section 4, we describe how analogical gestures can cohere over time to form larger analogical models. After characterizing analogical gestures, we can turn to the question of why cognitive scientists might care about them, drawing on prior findings about analogical reasoning in general and about gesture and cognition.

## 3. Representing relations in analogical gestures

Once we import a focus on relations and relational structure into the study of gesture—and into the study of abstract gestures in particular—a number of new questions pop into focus. To start, what kinds of relational structures are represented in gesture, and how complex do these relational structures get? Perhaps the most basic relation that is represented in gesture is that of *difference*, a kind of ontological relation. Gesture is so commonly used to contrast two entities, ideas, or propositions that the practice shows up in our spoken idioms ("on the one hand" and "on the other hand"). Again, it does not matter whether the entities contrasted are themselves concrete or abstract, what matters is that space is used—not to represent an actual spatial relationship between the entities in the world—but to represent that they are fundamentally different.

Also common is using gesture to place entities in a spatial arrangement that represents order along some abstract dimension, such as value, magnitude, time, and others. The best studied case of this use of gesture to date is temporal gestures, which locate entities or events according to a "timeline" (as seen in the egg and omelet example). Temporal gestures were first described in detail in English (Cienki, 1998), and have since been studied in global languages like Mandarin, as well as in indigenous languages like Aymara (South America) and Yupno (Papua, New Guinea) (see Cooperrider, Núñez, & Sweetser, 2014, for a review). Although these different languages use strikingly different spatial relations to represent temporal relations, all share the core feature that temporal relations are systematically represented in gesture as an ordered spatial arrangement. Scales of magnitude and valence are extremely common in everyday language and graphical culture and are likely widely realized in gesture as well, although they are not yet well studied (for some examples, see contributions in Cienki & Müller, 2008). Indeed, any dimension that is construed as having an ordered relational structure—with a less pole and more pole—is ripe for representation in analogical gestures.

In the simplest case, a speaker may place a single entity within an implicit ordered arrangement—placing "tomorrow" to the right (on an implicit horizontal timeline) or "the boss" up high (on an implicit vertical scale of power). Such gestures may be said to be tacitly relational—and thus analogical—insofar as they relate a mentioned entity to other unmentioned entities. The relation between an entity at one time point and the same entity at another time point can also be captured in gesture—these comparisons are commonly realized in gesture as movements. Increases and decreases in an entity's magnitude, for instance, may be represented as movements along the vertical axis (e.g., Cooperrider et al., 2016). Relatedly, changes in scalar properties such as pitch are also represented in gesture as shifting positions in vertical space. Indeed, such gestures are sometimes used in music education and in teaching tonal languages like Mandarin. The same gestural devices can be used to capture the relation between two entities on a single dimension.

Relational structure can get much more complex than a change in a single entity, or a relation between two entities on a single dimension. One type of further relational complexity is when two entities change at the same time. An example is the notion of a

*trade-off*—the idea that, as one thing undergoes a change, something else undergoes an opposite change. In a 2014 television interview, Christine Lagarde, acting director of the International Monetary Fund, produced a gesture to represent this concept while discussing how to manage inflation and interest rates. She says: "Again, it's a question of measure and balance. You know, obviously inflation rates and interest rates go together and sort of balance out. There is a trade-off between the two." As she says "trade-off" she holds both hands flat, palms facing downward, and rocks them in an alternating motion (see Fig. 2A). In a single gestural image, she thus captures the idea that there are two different entities—inflation rates and interest rates—and as one changes, the other changes in a roughly opposite way.[3]

For comparison, consider another example of a gesture representing the notion of a trade-off, also involving an alternating movement pattern (see Fig. 2B). In this case, James Steinberg, former Deputy Secretary of State, is making the point that the interests


Fig. 2. Two examples of gestures produced to represent the notion of a "trade-off." Both examples involve alternating motions of the hands, thus capturing the idea that, as one entity changes, another changes in the opposite way.

of emerging powers like India, China, and Brazil are not fundamentally at odds with the interests of the United States. He says: "So it's not a trade-off. This is not a 19th century competition of powers." As he says "trade-off," he moves both hands, fists closed, several times in an alternating in-and-out motion. Both examples involve alternating two-handed movements, but different hand shapes (open palms in the first example, fists in the second) and different directions of movement (up-down in the first example, and in-out in the second), making it clear that there is more than one way to represent a trade-off in gesture.

A trade-off is what Gentner (1983) termed a *relational abstraction*—a complex relational structure that comes to be stored as a whole (and that may have a verbal label, as in this case). Other examples of abstractions that may be ripe for gestural representation include reciprocity, quid quo pro, pre-emption, domino effect, Catch 22, vice versa, circular reasoning, vicious cycle, homeostasis, and many others. Although there does not appear to be a rigidly conventional "trade-off gesture"—as evidenced by variation in the forms used in our two examples—it remains an open question as to whether such relationally complex gestures only occur after an abstraction is in place. That is, do complex relational gestures show up only after an abstraction has already become crystallized and labeled, or might these gestures reflect abstract relational structure as it is being discovered and articulated for the first time?

## 4. Analogical models in gesture

Analogies take time to express. Just as it is not always possible to capture an apt comparison in a single word or phrase, it is not always possible to express a comparison in a single gesture. After all, we only have two hands, ten fingers, three spatial dimensions, and so much room within our reach. The trade-off gestures just described are remarkable in that they compress a substantial amount of relational information into a quick movement. While there are clear limits on what a single gesture can represent, speakers can skirt these limits by building up relational structure over time, gesture by gesture. We will refer to sequences of analogical gestures that cohere into larger spatial models of relational structure as *analogical models*.

Most work on gesture has taken single, isolated gestures as the unit of analysis. There are good practical reasons for this tendency, as looking at models rather than one-off gestures can be messy. Still, several researchers have noted that such models exist and have begun to study them more systematically. McNeill (2005), for example, noted how gesture features often recur over time, forming threads of visuospatial imagery that he has called "catchments." He also noted a related phenomenon by which speakers establish referents in space and then maintain those locations over stretches of discourse (akin to establishing referential loci in sign language; see Emmorey, 2002; Liddell, 1995; Taub, 2001). More recent studies have explored the conditions under which space is used to track locations (e.g., Perniss & Özyürek, 2015; So, Kita, & Goldin-Meadow, 2009). In another line of work, both signers in their signs and speakers in their gestures have been

found to build up models over time when describing concrete spatial layouts (Emmorey, Tversky, & Taylor, 2000). In this case, rather than merely echoing a previously established mapping between a particular referent and a particular location, the speaker or signer adds new spatial information that integrates with—and extends—information presented earlier.

The egg and omelet example contains the rudiments of an analogical model in the sense just described: The gestures are produced one after another and build on each other to form a single model. Perhaps more interesting would be cases in which a barebones relational model is established and then elaborated with subsequent gestures. Take, for example, gestures that accompany the phrase vice versa,[4] another of the relational abstractions mentioned earlier. In a first example, in Fig. 3, the interviewer Peter Slen is posing a question about how American political parties are often perceived as having ownership over particular issues. He asks: "Have there been issue ownership changes, where the Democrats owned it for awhile and now the Republicans own it, or vice versa?" As the gesture sequence begins, both of Slen's hands are out in front of his body. As he says "Democrats," he brings his left hand down on his left side (Fig. 3A); then with "Republicans," he brings his right hand down on the other side (Fig. 3B). Finally, as he says "vice versa," he rotates both hands over top of each other, as though manipulating something in the space between the two previously established locations (Fig. 3C).


Fig. 3. Two examples of gesture sequences that cohere into analogical models, both involving the phrase "vice versa." In each case, entities are first laid out on different sides of the speaker's gesture space (A,B; D,E) and then the relation between them is manipulated with a third gesture (C,F).

In a similar example, the psychologist Steven Pinker is arguing that grammatical errors are often a matter of using the wrong style for the occasion. He says: "Using the wrong style in either direction... a formal style when an informal one is called for—or vice versa—are both grammatical errors." His first gestures lay out the two entities involved: he brings his right hand crisply down on his right as he says, "formal style" (Fig. 3D), and then moves the same hand over to the left and crisply down when saying, "informal style" (Fig. 3E). Completing the sequence, he brings his hand between the two established positions, extends two fingers, and twists his wrist as though reassigning the entities to different positions (Fig. 3F). As with the two trade-off examples, the variation in form in the vice versa examples suggests that the gesture is not conventionalized.

Both vice versa sequences involve an integrated series of three gestures: The first two map entities to locations, and then the third operates on these locations with a new gesture. Longer and more complex sequences can, of course, occur. In a line of research conducted in collaboration with Dedre Gentner (Cooperrider et al., 2016), we have elicited explanations of positive and negative feedback systems, two examples of complex relational abstractions. Such systems cut across a number of content domains and are far from obvious, often eluding undergraduates (Goldwater & Gentner, 2015; Rottman, Gentner, & Goldwater, 2012). Although participants were not encouraged to gesture in our studies, almost all did. Many produced at least rudimentary analogical models, and some produced strikingly consistent and fully realized ones. An example of a consistent analogical model in gesture is partially illustrated in Fig. 4. The participant is introducing the basic structure and behavior of a positive feedback system. She says: "If there are two factors, one increases. That makes the other increase. And that, in turn, makes the first one increase more." To start, the participant lays out the two factors simultaneously in space (see Fig. 4A), one represented by her left hand and one by her right. She then shows a series of increases as vertical movements, first with her left hand (Fig. 4B), then with her right (Fig. 4C), and then again with her left (Fig. 4D). Her spatial model does not stop there: It is maintained throughout as she summarizes the overall dynamics of a positive feedback system, and then contrasts it with a negative feedback system.


Fig. 4. Examples of an analogical model in gesture, produced during an explanation of a positive feedback system. A first gesture (A) establishes the causal factors as locations in space; three subsequent gestures represent increases to the first factor (B), the second factor (C), and then the first factor again (D), as upward movements.

Interestingly, examples of well-developed analogical models in gesture are not limited to explanations of scientific or technical concepts. Another case of such models comes from Enfield's analysis of how Lao speakers express everyday kinship concepts in gesture (Enfield, 2005). The richness of the phenomenon comes across especially vividly during explanations of the notion of a "sibling exchange." In Laos, when a couple marries, it is common for a sibling of the wife and a sibling of the husband to also marry—a multi-family arrangement known as a "sibling exchange." However, there are also important restrictions: While an older sibling of the husband can marry an older sibling of the wife, and a younger sibling of one can marry a younger sibling of the other, it is not allowed for an older sibling of one to marry a younger sibling of the other. As a speaker explains this prohibition, he produces a series of gestures that use left and right space to contrast two families and vertical space to arrange the children within each family by age (younger in age is represented as lower in space). Accordingly, to show that an older sibling of the bride and an older sibling of a groom may marry, the speaker places two hands above his head, showing that they are both "high" and at the same "height." Later, to represent the prohibited arrangement in which a younger sibling of one spouse marries an older sibling of the other, he crosses his forearms and thereby shows the violation of "parallelism." Enfield frequently refers to this phenomenon as the production of gestural "diagrams." The word is apt in that it connotes sparseness and perhaps also a focus on relations rather than attributes. However, we favor *analogical model* because the term *diagram* applies equally well to concrete visuospatial content (e.g., a diagram of the circulatory system) and to purely abstract content (e.g., a diagram of an organizational hierarchy) (for discussion of parallels between diagrams and gestures, see Tversky, 2011).

## 5. Questions and predictions

Once we start seeing gesture through the eyes of the structure mapping framework that Gentner and colleagues have developed, a number of promising possibilities for further research suggest themselves. In this section, we consider a few of the most tantalizing, using as a guide questions and predictions that have come out of work on analogical reasoning and gesture more generally, and out of our own collaboration with Dedre Gentner. Some of these questions and predictions concern analogical gestures specifically, whereas others concern relational gestures generally, be they iconic or metaphoric.

### *5.1. Processing analogical gestures*

A first question that arises is whether listeners process analogical gestures and, if so, whether this processing shares features with how analogy and metaphor are processed by listeners more generally. There is abundant evidence that listeners glean information from speakers' gestures, with much of the work focusing on processing iconic gestures (see Hostetter, 2011, for a review). Early findings suggest that analogical gestures also convey information and may have important consequences for reasoning. For example, Jamalian

and Tversky (2012) found that observing temporal gestures that represented phenomena as either circular or linear, or that depicted events as happening sequentially or in parallel, led participants to reason about these phenomena in correspondingly different ways. Listeners have also been found to process analogical gestures that represent aspects of sound spatially. For instance, when people judge the pitch of a sung note, their ability to do so is biased if the singer also produces gestures that represent pitch vertically (Connell, Cai, & Holler, 2013). Relatedly, gestures that represent pitch contours (e.g., a falling tone represented with a gesture moving rightward and downward) can help English speakers learn Mandarin words (Morett & Chang, 2014).[5]

In several studies on metaphor processing, Gentner has shown that people are better at processing incoming information when it is consistent with a mapping already established in the discourse (e.g., Gentner, 2001; Gentner, Bowdle, Wolff, & Boronat, 2001; see also Thibodeau & Durgin, 2008). This phenomenon has been called the "metaphor consistency effect." For example, after reading sentences involving one of two widespread temporal models used by English speakers—either the ego-moving model ("We are approaching the deadline") or the time-moving model ("The deadline is approaching us")—subjects were slower to process a target sentence that switched to the other model, compared to a target that maintained the initial model. We should expect a similar processing cost in listeners when a speaker switches between analogical models in *gesture*. Interestingly, note that such a processing cost could, in some cases, be beneficial in the long term. In an educational context, being exposed to multiple models for the same concept might slow the learner down, but in the end lead the learner to new insights (i.e., desirable difficulties; see Bjork & Bjork, 2014), whether by implicitly comparing models or some other mechanism.

Good analogies relate a base and a target in a systematic, structurally consistent way (Gentner, 1983; Gentner & Markman, 1997). For instance, there must be a one-to-one correspondence between elements in the base representation and elements in the target representation. Violations of structural consistency in analogical gestures should impede processing, or lead to erroneous inferences. Consider the analogical model of positive feedback discussed earlier (Fig. 4) in which the speaker assigns a factor to each hand and shows a series of increases in those factors. Once the assignment of factors to hands has been made, showing a movement of the wrong hand would be a violation of structural consistency. Interestingly, there is already evidence that adults—and even young children—track the locations of entities assigned to abstract locations in gesture space (Gunter, Weinbrenner, & Holle, 2015; Smith & Kam, 2015). A question for future work is how violations of structural consistency impact the processing of extended analogical models.

### *5.2. A relational shift in gesture?*

A major focus of Genter's research has been analogical thinking in learning and development. Early on, she noted a "relational shift" that plays out in children's learning (e.g., Gentner, 1988; Gentner & Rattermann, 1991). When first learning about a given domain, children focus on objects and attributes, shifting to a focus on relations as they learn more. An example of this shift is seen in children's preferences for—and interpretations

of—metaphors. Young children judge metaphors that focus on attributes (as in the earlier "The sun is a grapefruit" example) as more apt than metaphors that focus on relations (as in the earlier "That job is a jail" example). Some metaphors allow either kind of interpretation, one based on shared attributes between the base and target attributes, and one based on shared relations (e.g., "Tires are shoes"). Interestingly, in cases of these "double metaphors," children prefer an interpretation based on attributes, whereas adults prefer relational interpretations (Gentner, 1988; Gentner & Clement, 1988). We might predict that these patterns would extend to gestures. Children might begin by producing metaphoric gestures that highlight attributes and only later come to produce metaphoric gestures that highlight relations—that is, analogical gestures. In fact, we might also make this prediction for iconic gestures, that is, that children would first produce gestures that depict attributes of objects and actions, and only later purely relational iconics. The same developmental shift could also be seen in the ability to *process* gestures. Young children may not be able to make sense of the analogical gestures we have described, and when presented with abstract gestures that represent both attributes and relations, they might key on attributes and ignore the relational information.

A similar relational shift may be observed in the acquisition of expertise (Rottman et al., 2012) and even in the history of science (Gentner & Jeziorski, 1993). Indeed, the relational shift is not driven by development per se, but by learning about a new domain. Thus, in the right domain, it might be possible to observe an increased use of analogical gestures (and relational iconics) among adult experts compared to adult novices. In fact, Gentner and colleagues have begun to examine evidence for a relational shift in another visuospatial medium—*sketching*. Jee et al. (2014) found that, relative to novices, geoscience experts included more relational symbols such as arrows in their sketches.

### *5.3. Learning*

Relations are important for how we understand the world but are, at their core, nonobvious. Gentner (2003, 2010) has proposed that language plays a critical role in highlighting relations so that we can notice them, remember them, and reason about them. One way this happens is that relational words like *middle* and *barrier* invite learners to compare instances where such labels are used, and this process of comparison leads learners to form new, abstract knowledge. Could relational gestures—whether iconic or analogical—play the same kind of role in highlighting relations for learners? And how would the role of gesture compare to the role of language? As our examples have shown, analogical gestures make use of a limited vocabulary for representing relational structure as spatial structure—entities are locations, conceptual dimensions are ordered spatial arrangements, changes are movements, and so on.[6] Seeing gestures that use this same restricted vocabulary for disparate phenomena may lead learners to compare those phenomena and pull out valuable abstractions.

One case where the power of relation-highlighting gestures has already been demonstrated is in learning about mathematical equivalence (Goldin-Meadow, 2003), a principle involved in solving problems such as: $4 + 3 + 6 =$ ____ $+ 6$. An effective solution

strategy is to group the first two addends (4 and 3) and put the sum into the blank. Such a strategy can be demonstrated in gesture by using a "V" hand shape to simultaneously point to the 4 and 3—thus highlighting the relation of grouping—and then pointing to the blank. In fact, learners benefit from this grouping gesture even when the fingers of the "V" point to the wrong numbers, suggesting that highlighting a relation helps over and above highlighting particular numbers or locations (Goldin-Meadow, Cook, & Mitchell, 2009). Highlighting the grouping relation in this way also helps children generalize the strategy to new types of equivalence problems (Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014). Novack et al. (2014) compared the effects of the relational grouping gesture just described to a more action-like version of the gesture in which the learner mimics picking up the two addends. Note that both versions of the gesture include relational information about grouping, but the action-like gesture also represents potentially distracting action attributes, such as a grasping hand shape. The key finding was that the children who learned grouping through the purely relational gesture performed better on transfer problems.

An important caveat is that, before learners can benefit from relational gestures, they must first understand *how* those gestures represent relational structure. In the case of the grouping gesture just described, the relation may be relatively accessible because the entities that are related—numbers on a whiteboard—are physically present in the speech situation. In many of the analogical gestures we have considered, however, the entities are not only *not* present in the speech situation, but they also have no concrete manifestation as entities. If a learner fails to understand the mappings involved in an analogical model expressed in gesture, that model may be more of a stumbling block than a stepping stone. Analogical gestures may be a powerful tool, but only when deployed at the right time, for the right learner. Indeed, emerging evidence suggests that gesture sometimes helps and sometimes hinders, depending on the specifics of the gesture, the situation, and the learner (Congdon, 2016; Goldin-Meadow & Beilock, 2010; Post, Van Gog, Paas, & Zwaan, 2013).

## 6. Conclusion

Analogies are happening all around us. In lecture halls, courtrooms, laboratory meetings, and television interviews, they are being proposed, elaborated, and evaluated. Much prior work has focused on the analogies that show up in language. But they also show up in another medium: the gestures people produce when they talk. This fact has two important implications. One is that there is a naturalistic and omnipresent source of data on analogical reasoning and thinking that is going untapped by researchers interested in analogy. Looking closely at how analogies manifest in gesture may offer fresh insights into the analogical mind, insights that might be hard to glean from language alone. Another implication is that, just as analogy researchers may be missing out on an illuminating source of evidence, gesture researchers may be missing out on an illuminating theoretical framework, one that has been developed and fine-tuned over decades by Dedre Gentner and her colleagues. In short, gesture can inform our understanding of analogy, and vice versa.

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## Notes

1. In both Taub's (2001) and Emmorey's (2014) treatments, metaphorical iconicity in sign language is said to involve a "double mapping." The first mapping is between some abstract idea and a visuospatial mental representation; the second mapping is between that visuospatial mental representation and the bodily representation. For simplicity, we will treat this as a single mapping between an abstract idea and its gestural representation.
2. It can be misleading to try to judge the abstractness of a gesture by its co-occurring speech. For instance, if a speaker produced an attribute metaphor in speech, "The sun was a grapefruit," while representing an imagined spherical object between the hands, this would be an iconic gesture because it represents an actual visuospatial attribute of the sun—its spherical shape. Even relational metaphors—that is, analogies—in speech do not necessarily go with gestures that represent relations. If a speaker said, "This job is a jail," with a gesture representing someone holding prison bars, the gesture would be representing *attributes*—what it looks like to hold prison bars—and not the relation of confinement more generally. Of course, to get the intended meaning, it is necessary to identify common relational structure between job and jail: The job is confining to the person who has it, just as a jail is confining to a prisoner. But that is not what the gesture represents. In what we are considering analogical gestures, relations themselves are given visuospatial representation, and the speech may or may not be obviously metaphorical.
3. A possible interpretation of Lagarde's gesture is that it is inspired by the image of a balance scale, with parts that move up and down in complementary fashion. Such a motivation would not make the gesture iconic—however, she is not representing actual movements in space but abstract changes. It is nonetheless interesting to note that some analogical gestures may be inspired by ready-made concrete images such as a balance scale, whereas others may be cobbled together on the spot.
4. Etymologically, the phrase vice versa involves a spatial analogy—the Latin means "in-turned position"—but this is probably opaque to most English speakers.
5. Not all analogical gestures representing properties of sound have been found to have such consequences. For instance, Kelly, Hirata, Manansala, and Huang (2014) found that gestures representing vowel length contrasts did not benefit English speakers' learning of Japanese words.

6. Interestingly, many of the components of this basic vocabulary also show up in everyday language (Lakoff & Johnson, 1980) and in diagrams (Tversky, 2011).

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## Appendix A: Links to gesture clips

Fig. 1. Sean Carroll in a lecture (see 0:15 to 0:29): https://www.youtube.com/watch?v=rEr-t17m2Fo

Fig. 2A. Christine Lagarde in a television interview: https://archive.org/details/BLOOMBERG_20140412_000000_Charlie_Rose#start/1500/end/1560

Fig. 2B. James Steinberg in a television interview: https://archive.org/details/KRCB_20110625_060000_Charlie_Rose#start/448.5/end/470.1

Fig. 3A–C. Peter Slen in a television interview: https://archive.org/details/CSPAN2_20141013_053500_Book_Discussion#start/550/end/560.7

Fig. 3D–E. Steven Pinker in a lecture: https://archive.org/details/CSPAN2_20141225_160600_Key_Capitol_Hill_Hearings#start/237.7/end/248