Spatial Gestures Point the Way: A Broader Understanding of the Gestural Referent

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Abstract

We investigated the use of iconic and deictic gestures during the communication of spatial information. Expert structural geologists were asked to explain one portion of a geologic map. Spatial gestures used in each expert's response were coded as deictic (indicating an object in the conversational space), iconic (depicting an aspect of an object or event), or both deictic and iconic (indicating an object in the conversational space by depicting an aspect of that object). Speech paired with each gesture was coded for whether or not it referred to complex spatial properties (e.g. shape and orientation of an object). Results indicated that when communicating spatial information, people occasionally use gestures that are both deictic and iconic, and that these gestures tend to occur when complex spatial information is not provided in speech. These results suggest that existing classifications of gesture are not exclusive, especially for spatial discourse.

Keywords: gesture; deictic; iconic; highlighting

Introduction

People communicate and focus the listener's attention to different levels of spatial information in speech and gesture. Spatial information is expressed in gesture both for communicating with others and for individual problem solving (Alibali, 2005). Common spatial activities (e.g. giving directions) (Lavergne & Kimura, 1987; Allen, 2003) and the communication of complex spatial ideas (e.g. geology) (Liben, Christensen, & Kastens, 2010) often include gesture.

Communicating three-dimensional spatial relationships using only language is difficult. As most spatial words are qualitative and are not apt for asserting metric spatial information (Tversky & Lee, 1998), gesture is critical in conveying relations that cannot be easily expressed in speech. Gesture allows one to communicate thoughts that do not easily fit into the categorical system language offers (Goldin-Meadow, 1999). The literature provides a classification for spontaneous gestures made during regular discourse (e.g. McNeill, 1992; Krauss, Chen, & Chawla, 1996; Ekman & Friesan, 1969). This study investigates whether the existing classification is appropriate for gestures that occur during spatial discourse involving complex spatial reasoning.

Extant research indicates that gestures occur more frequently when communicating spatial information, than when communicating non-spatial information (e.g. Alibali, Heath, & Myers, 2001; Rauscher Krauss, & Chen, 1996; Lavergne & Kimura, 1987). For example, Alibali, Heath, and Myers (2001) asked participants to narrate a *Tweety and Sylvester* cartoon to a naïve addressee, and found that the speakers were nearly twice as likely to produce gestures with units that contained spatial prepositions than with units that did not. Furthermore, gesture frequency varies depending on speech topic. Lavergne and Kimura (1987) asked participants to speak for six minutes each on neutral topics (e.g. describe your typical school day routine), verbal topics (e.g. describe your favorite books and authors), and spatial topics (e.g. describe the route you would take to walk from the university's main library to the main entrance of campus). Participants produced twice as many gestures when speaking about spatial topics than when speaking about verbal or neutral topics.

People convey information using gestures in many different ways. For the purpose of this paper, gestures are defined as movements of the hands and arms that are produced when engaging in effortful cognitive activity (e.g. speaking, problem solving) (Alibali, 2005). Much of the literature has focused on two broad categories of movements: beat and representational gestures. Beats are hand movements that match the rhythm of the associated speech. For example, when reciting his grocery list, the speaker moves his finger up and down for every item on the list, "apples, bananas, cheese, and bread." Within the category of representational gestures (gestures that convey semantic content by virtue of shape, placement, or motion trajectory of the hands - e.g. pointing to the right to mean "right") (Alibali, 2005), gestures can be categorized as *iconic* or *deictic* (McNeill, 1992). These two broad types of gesture are the focus of this paper.

Iconic gestures "bear a close formal relationship to the semantic content of speech" (McNeill, 1992, p.12). For example, when describing a scene from a comic book in which a character bends a tree back to the ground, the speaker makes gripping and pulling gestures as he or she describes the same actions (McNeill, 1992). *Deictic* gestures indicate entities in the conversational space (the physical space visible to both participants of the conversation). Usually, deictic gestures are pointing gestures that indicate objects and events in the concrete world (McNeill, 1992). For example, when choosing a puppy at the pet store, the child points to the puppy that he wants to buy.

Starting at 9 to 12 months of age, humans use pointing gestures to indicate objects in the environment (Bates, 1976; Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). Though pointing is an easy and efficient way of indexing an object in space, and although the distinction between iconic and deictic gestures may be helpful in classifying non-spatial discourse, we propose that in tasks involving the communication of complex spatial information, the current classification may be limiting. The current classification is implicitly mutually exclusive, perhaps for methodological reasons, such that gestures would be classified as either deictic or iconic, but not both. If this assumption is incorrect, researchers could be in danger of missing potentially informative gestures that are both deictic and iconic.

The existing classification does not capture gestures that simultaneously draw the listener's attention to a specific object and represent two or more dimensions of spatial information. Gestures that are not pointing (or tracing) can provide "deictic" information; for example, an "iconic" gesture that resembled an object could be used to refer to the object. Such gestures have been reported anecdotally, Roth (2000) details a middle school science student explaining to his class the mechanism behind a pulley system. In his explanation, the student says, "Pull here," and used a gesture that made salient both the location and direction of the pull (Roth, 2000). The gesture is both iconic and deictic. As in this example, one could use the hand to draw the listener's attention to the form and location of something in the environment. Since we know that listeners make use of the information in a speaker's gestures (e.g. Alibali, Flevares, & Goldin-Meadow, 1997; Goldin-Meadow & Sandhofer, 1999) and spatial concepts can be hard to convey in speech alone, we may learn more about the function of gestures by observing their use in discussion of complex spatial settings.

Thus, the current study examines the use of deictic gestures during a spatial task. The results presented here are part of a larger study investigating the communication of spatial information by structural geologists. Structural geology is a spatially complex and cognitively demanding field, where experts gesture extensively when they speak. A reason to begin research in this domain is that these experts' gestures are likely to focus on complex spatial information. In the future, we plan to investigate if the patterns of communication found here are also present in other, more common, spatial situations. In the study, expert structural geologists were asked to complete a series of tasks, including explaining the geology of two regions using geologic maps. Here we investigate experts' use of pointing gestures versus iconic gestures to indicate one or more objects on a map.

One reason geologists gesture is they are often in a situation where it is not possible to see the entire object of interest. Since the information found on an outcrop is complex and only one face of a structure is usually visible (providing two-dimensional information), experts could use iconic gestures to highlight critical features since the whole three-dimensional structure is not observable (Frodeman, 1995). A geologic map shares some of the same characteristics. The information found on a geologic map is quite complex, and it is a two-dimensional representation of three-dimensional structures. Based on our observations of experts in the field, combined with the complexity and two-dimensional quality of a geologic map, we hypothesize that structural geology experts will use iconic gestures, in addition to pointing gestures, to index specific geological entities. We predict that they will use iconic gestures for the following reasons: 1) pointing gestures may be ambiguous as the referent is located within a complex image with overlapping features; and 2) the object of interest is a three-dimensional structure – something that is not shown, but needs to be inferred from the map as only a slice through the three dimensional form may be visible at the surface. To test our hypothesis and characterize the gestures experts use, we coded experts' gestures for type (deictic, iconic, or both), and kind of spatial information (point, line, plane, or form, process/event) for responses to one question about one geologic map.

Methods

Participants

Thirty-four attendees at a Structural Geology and Tectonics Conference participated in the study. To focus on experts' gestures, we restricted analysis to data from those participants with a PhD who were also professors at an academic institution. Thus, data from ten participants were excluded. Data from one additional expert was excluded because he or she was bilingual in English and American Sign Language. Therefore, data from 23 expert structural geologists (14 men, 9 women, M_{age}=45.8 years, age range: 33-60 years) was used for this analysis.

Materials

Explanations were recorded with a Canon HD Video Camcorder HV20 (3.1 Megapixels). The map used for this portion of the study was a *Geologic Map of the Black Hills Area, South Dakota and Wyoming* (DeWitt, Redden, Buscher, & Wilson, 1989). It was presented on a flat 78 cm high table.

Design and Procedure

The study took place in a quiet room where only the experimenter and the participant were present. After arriving, the participant completed the consent process. He or she was then asked to stand behind the empty table placed in the center of the room. Throughout the course of the study, the experimenter stood directly across from the participant, approximately five feet away.

The experimenter explained that this was a study investigating teaching and reasoning about geologic maps. A *Geologic Map of the Black Hills Area, South Dakota and Wyoming* (DeWitt, Redden, Buscher, & Wilson, 1989) was then placed on top of the table so the participant could see it. Participants were first asked whether they were familiar with the map before beginning the task. They were then asked to pretend that the experimenter was a geology undergraduate student with some domain knowledge, specifically having completed an introductory course and one or two upper level geology classes. The task was to explain what structures were under the ground along a specific cross-section, and explain how he or she knew. This task would be a familiar one to a structural geologist, and the map was designed to provide this information. After providing the prompt, the experimenter indicated the cross-section region on the map for the participant. Gesturing was never mentioned. Responses were audio and video-recorded.

Coding

Each of the experts' spontaneous gestures and accompanying speech was coded by the first-author. Inter-rater reliability was established by having a second trained coder who independently coded a subset (20%) of the responses. Each gesture was coded for the following things:

Speech The speech accompanying each gesture was transcribed. Due to the complexity of the information communicated by the experts, participants' speech was used to clarify the information represented in the gesture. Furthermore, speech accompanying each gesture was coded for whether it included information about a *structure* (e.g. dome, mountain) or provided *orientation* information (e.g. layers are steeply dipping). Inter-rater agreement for *speech* was κ=0.80 (n=182 gestures).

Gesture Using the accompanying speech to clarify, each gesture was coded for whether or not it represented a spatial property (e.g. the spatial relations between two rocks). See Atit, Shipley, and Tikoff (2013) for more information about the spatial properties represented in gesture. Inter-rater agreement for *spatial property* represented was κ=0.79 (n=182 gestures). Gestures that represented spatial properties were further characterized as follows.

Spatial Information The categories for the *spatial information in a gesture* were created based on the dimensional information that the gesture conveyed. A gesture that conveys 1D information indicates a *point*, a gesture that conveys 2D information indicates a *line*, gestures that convey 3D information indicate *planes* and *forms*, and gestures conveying 4D information indicate *changes* or *processes*. For more information on this categorization of gestures, see Atit, Shipley, and Tikoff (2013).

Each gesture was coded for one of the following six spatial categories: 1) *point*: hand-shape used was typically an index finger indicating a location in space, 2) *line*: hand shape typically was an index finger indicating a line in space, 3) *plane*: hand shape typically was a flat palm indicating a plane in space (generally providing information about orientation), 4) *form*: hand formed a three-dimensional shape in space (e.g., forming the hand in the shape of a dome or moving the hand to sculpt the shape of a dome), 5) *process/event*: hand conveyed a process or an event (e.g., hand showing the movement of magma representing an intrusion), and 6) *other*: all other gestures. Inter-rater agreement for *spatial information in gesture* was κ=0.81 (n=182 gestures).

Function Type Each gesture was also categorized into one of the following four types: 1) *deictic*: if it indicated an entity on the map (e.g. pointing to a specific fault line on the map, or tracing the fault line on the map), 2) *iconic*: if it "bears a close relationship to the semantic content of speech" (McNeill, 1992, p. 12), and depicted an aspect of an object within the conversational space (e.g. a curved hand used to represent a fold), 3) *both*: if it simultaneously drew the listener's attention to a specific object on the map while depicting an aspect of it (e.g. using a curved hand to show the shape and location of a fold on the map), or 4) *unrelated*: if it could not be classified into any of the three type categories. Inter-rater agreement for gesture type was κ=0.82 (n=182 gestures).

Results

Spatial Gestures

On average, each participant gestured 51.87 times over the course of the task (*SD*=26.94). We found no difference in the number of gestures produced by men (*M*=51.00, *SD*=29.14) versus women (*M*=53.22, *SD*=24.75), *n.s;* and no difference in the number of gestures produced by participants who were familiar with the map (*M*=58.60, *SD*=30.93) versus those that were not familiar with the map (*M*=46.69, *SD*=23.37), *n.s.*

When looking at the information conveyed within gestures, we found that participants gestured more about spatial information (gestures conveying a *spatial property)* (*M*=0.73, *SD*=0.14) than about non-spatial information (*M*=0.27, *SD*=0.14), $t(22) = 7.96$, $p<.001$. All means and standard deviations for the following analyses are provided in Table 1.

Table 1: Means and standard deviations of gestures

	Point	Line	Plane/Form/Process/Other
Deictic	*M*=0.11	*M*=0.20	*M*=0.06
	SD=0.08	*SD*=0.15	*SD*=0.07
Non-Deictic	*M*=0.01	*M*=0.01	*M*=0.37
	SD=0.02	*SD*=0.02	*SD*=0.22

Note. Table presenting means and standard deviations across participants for the different kinds of gesture (point, line, plane/form/process/other) and for different types of gesture (deictic, non-deictic). The descriptives reported here are the means and standard deviations of the proportions of spatial gestures for each category. As there were no differences between the plane, form, process, and other categories, we collapsed across these categories. Gestures that were deictic indexed an object on the map, and could be composed of point, line, plane, form, process, and other gestures. Gestures that were non-deictic did not index an object on the map, but also could be composed of point, line, plane, process, and other gestures.

First, we looked at what proportion of spatial gestures was pointing gestures. On average, 12% of each participant's spatial gestures involved pointing (*M*=0.12, *SD*=0.09). An overwhelming majority of those were identified as deictic (*M*=0.11, *SD*=0.08), with only 1% of gestures being iconic and pointing (*M*=0.01, *SD*=0.02), $t(22)=5.98$, $p<.001$. Pointing gestures were mainly used to index an object in the conversational space.

Second, we considered the other cases of deictic gestures. The first notable observation is that while pointing maybe the prototypical deictic gesture, in this context the most frequent deictic gesture was tracing a line in the conversational space. On average, 21% of each participant's spatial gestures were of this kind (*M*=0.21, *SD*=0.15). More line gestures were classified as deictic (*M*=0.20, *SD*=0.15), than non-deictic (*M*=0.01, *SD*=0.02), $t(22)=5.83$, $p<.001$, and the frequency of deictic line gestures (*M*=0.20, *SD*=0.15) was significantly greater than pointing gestures (*M*=0.11, *SD*=0.08), $t(22)=3.24$, $p<.01$.

Finally, when we consider the spatial gestures that were plane, form, or process/event gestures, we find that most of these were iconic (*M*=0.37, *SD*=0.22). However, an intriguing portion was both iconic and deictic (*M*=0.06, *SD*=0.07). The proportion of gestures classified as "both" iconic and deictic was significantly different from 0, $t(22)=4.25$, $p<.001$. Thus, most of the gestures made by experts could be classified as iconic or deictic, but there were a significant number of gestures that were both deictic and iconic. Experts in this task used complex iconic gestures to index objects in the conversational space.

Gestures Classified as Both, Iconic and Deictic

To further explore the information represented in the gestures that were both deictic and iconic, we categorized them by the *spatial information in the gestures*. About half of the 6% represented planes (*M*=0.03, *SD*=0.04) and half represented forms (*M*=0.03, *SD*=0.05). Less than 1% of all gestures represented a process or event, or other kind of information. Experts may have used the planar and form gestures because the task was to explain the structures at a line of cross-section where orientation and shape information is not readily visible on the map. Without visible support for this spatial information in the diagram, experts may have employed gestures to ensure the three-dimensional referent was clear.

Lastly, we investigated the information conveyed in *speech* when experts employed these iconic and deictic gestures compared to when they pointed or traced to indicate an object. To make this comparison, we computed the following for each participant: 1) the proportion of pointing deictic gestures paired with spatially complex *speech* (speech containing structure or orientation information) relative to the total number of pointing deictic gestures; 2) the proportion of line deictic gestures paired with spatially complex *speech* relative to the total number of line deictic gestures; and 3) the proportion of plane and form gestures classified as both iconic and deictic paired with spatially complex *speech* relative to the total number of plane and form gestures classified as both iconic and deictic.

We found that a greater proportion of pointing deictic gestures were paired with spatially complex *speech* (*M*=0.34, *SD*=0.36) than planar/form iconic and deictic gestures, (*M*=0.04, *SD*=0.12), $t(22)=3.57$, $p<.01$. Similarly, more line deictic gestures were paired with spatially complex speech (*M*=0.27, *SD*=0.23) than planar/form iconic and deictic gestures, $t(22)=3.91$, $p<.01$. Thus, experts used gestures classified as both iconic and deictic especially in instances where the complex spatial information was not provided in speech.

Discussion

This study investigated the relevance of an existing distinction made in the gesture literature, iconic versus deictic gestures, within the realm of communicating spatial information. Traditionally, deictic gestures are defined as hand movements that indicate entities in the conversational space and usually consist of pointing (McNeill, 1992). Iconic gestures are hand movements that "bear a close formal relationship to the semantic content of speech" (McNeill, 1992, p.12), and generally do depict some aspect of an object in the conversational space.

Data from this study indicates that when asked to explain the structures present in a section of a geologic map, expert structural geologists use gestures that can be classified as deictic or iconic, along with gestures that fall in both categories. When using gestures traditionally classified as deictic, experts tended to trace more than point to draw the listener's attention to an object on the map. When using gestures traditionally classified as iconic, we found that experts used some iconic gestures to indicate an object on the map. Furthermore, gestures that were both iconic and deictic and represented information about planes and forms, tended to occur when there was no spatially complex information (e.g. structure or orientation information) conveyed in speech.

A number of studies have shown that gestures are useful in separating relevant from irrelevant information (e.g. Roth, 2000; Lozano & Tversky, 2006; Heiser, Tversky, & Silverman, 2004). Gestures help organize the conversational space into a salient foreground and an unrepresented, more diffuse background. Researchers in the past have likely focused on pointing because this hand shape is the most common one used to indicate the foreground. In contrast, here we replicate previous work (e.g. Lozano & Tversky, 2006; Heiser, Tversky, & Silverman, 2004) that has found that when the referent is complex and includes multiple kinds of information (e.g. maps), the speaker also uses tracing gestures to highlight objects for the listener. For example, Lozano and Tversky (2006) asked participants to explain to a listener how to assemble a piece of furniture, and found that participants used tracing gestures in addition to pointing gestures to draw the listener's attention to individual pieces (Lozano & Tversky, 2006). Heiser et al. (2004) asked pairs of students to use a campus map to design and produce an optimal emergency rescue route. They found that students also used tracing gestures along with pointing gestures to focus their partner's attention to specific aspects of their sketch and to highlight certain routes (Heiser, Tversky, & Silverman, 2004). We suspect that speakers used tracing gestures because pointing alone may be ambiguous when the referent has significant spatial extent and when it does not have clear boundaries.

The results from our study reveal an interesting type of gesture that is used to draw the listener's attention to an object. Experts in our study used complex gestures traditionally classified as iconic to highlight objects on the geologic map. A geologic map presents a horizontal cross-section through the three-dimensional topography of a region. Therefore, many objects of interest to a geoscientist will be three-dimensional structures that are not completely visible at the surface. Indeed what is visible at the surface may be a slice through a three-dimensional form. Since the two-dimensional information presented on the map does not directly resemble the actual three-dimensional form of these objects, the expert may use gesture to provide the listener with the missing information. For example, the elliptical outcrop pattern of rock layers presented on the map in this study does not resemble the three-dimensional form of the dome in the Black Hills region. Furthermore, it can be difficult to determine the orientation of the rock layers within a domal structure on a geological map because the inclination of the rock layers is typically represented using a symbol. Thus, the expert uses gestures to depict the shape of the dome and planar gestures to show the orientation of the layers in space. Whether it is the two-dimensional characteristic of the map, or the penetrative nature of geological structures that elicits this special type of gesture is a question for future research. For example, would an architect use gestures that could be classified as both iconic and deictic when explaining a blueprint of a building?

Finally, gestures classified as both iconic and deictic were used in instances where the spatially complex information is not provided in speech. For example, an expert represents the orientation and location of a layer of rocks on the map while referring to their relative ages in speech. Since complex spatial information is difficult to convey using language (Tversky & Lee, 1998) and gesture allows one to communicate thoughts that are not easily conveyed in speech (Goldin-Meadow, 1999), perhaps the speaker uses this type of gestures when providing multiple levels of information (e.g. location and orientation information) in language alone becomes difficult. Or, perhaps the expert could not produce the gesture and speech at the same time due to the cognitive load required by the task. A more global analysis of speech in the future can address this question.

One potential limitation of the current study may be that the experts were asked to pretend that the experimenter was a geology undergraduate to whom they were explaining the cross-section. It is possible the experts' language and gestures would have differed if they were providing explanations to real geology undergraduates. This seems unlikely as the experts were obviously engaged in their answers to the questions. Nevertheless, studies collecting and analyzing interactions between experts and novices in the field are in progress.

Supported by the findings of this study, we argue that the existing types of representational gestures (e.g. iconic and deictic) should not be treated as exclusive categories – overlap between the two types exists. People do use iconic gestures (e.g. planar gestures) to indicate, or highlight, objects in the world when the important spatial information is three-dimensional. One open question is whether the number of gestures that fall into "both" categories is related to the spatial complexity of the information conveyed. Perhaps the communication of more spatially complex information elicits a greater use of this special type of gestures.

Understanding how different types of gestures are employed in simple communicative contexts to highlight and convey complex spatial information may serve as the foundation for developing pedagogical techniques for conveying spatial information. A richer understanding of the different types of gestures could inform geology professors, and science professors in general, about how to most effectively communicate information to their students.

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