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I see it in my hands' eye: Representational gestures reflect conceptual demands

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The Information Packaging Hypothesis (Kita, 2000) holds that gestures play a role in conceptualising information for speaking. According to this view, speakers will gesture more when describing difficult-to-conceptualise information than when describing easy-to-conceptualise information. In the present study, 24 participants described ambiguous dot patterns under two conditions. In the dots-plus-shapes condition, geometric shapes connected the dots, and participants described the patterns in terms of those shapes. In the dots-only condition, no shapes were present, and participants generated their own geometric conceptualisations and described the patterns. Participants gestured at a higher rate in the dots-only condition than in the dots-plus-shapes condition. The results support the Information Packaging Hypothesis and suggest that gestures occur when information is difficult to conceptualise.

When people talk about spatial objects and events, they often produce representational gestures, or movements of their hands and arms that depict the image they are describing (McNeill, 1992). Such gestures resemble

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underlying mental representations (Alibali, 2005; Alibali, Bassok, Solomon, Syc, & Goldin-Meadow, 1999; Beattie & Shovelton, 2002), even when the speaker does not convey the same spatial ideas in speech (Church & Goldin-Meadow, 1986; Roth, 2002). Conveying spatial ideas through gestures might facilitate communication by enhancing listeners' comprehension. However, speakers still gesture even when their listeners cannot see them (Alibali, Heath, & Myers, 2001; Cohen & Harrison, 1973) and, at least in some instances, listeners' comprehension is not enhanced from seeing a speaker's gestures (Krauss, Dushay, Chen, & Rauscher, 1995). These facts have led many researchers to suggest that gestures are not produced solely to help listeners understand.

In addition to any role they may play in facilitating comprehension, representational gestures may also benefit the speaker more directly. One possibility is that gestures activate mental images and maintain them in the visuo-spatial sketchpad of working memory (see Baddeley, 1986). Speakers produce more representational gestures when describing spatial information that must be retrieved from memory than when describing a spatial image that is visually present (de Ruiter, 2001; Morsella & Krauss, 2004; Wesp, Hesse, Keutmann, & Wheaton, 2001). Such evidence has led some researchers to conclude that gestures may actually facilitate the retrieval of spatial information. However, such a memory activation account of gestures cannot explain why individuals gesture primarily when they are expressing spatial information in speech, rather than when they are silently thinking about spatial information. The close co-occurrence of speech and gestures suggests that, rather than being involved with memory demands more generally, speech-accompanying gestures are specifically associated with the cognitive demands involved in speaking about spatial information.

Speech production is a cognitively demanding task. Levelt's (1989) influential model describes three stages of speech production: conceptualisation, formulation, and articulation. Formulation is further divided into two substages: lemma selection (sometimes called grammatical encoding) and lexeme selection (sometimes called phonological encoding). During conceptualisation, a speaker generates prelinguistic thoughts, decides which concepts should be mentioned, and combines the prelinguistic concepts into propositional form. During formulation, this propositional form is matched with linguistic units (or lemmas) in the mental lexicon and these units are coordinated with grammatical rules that will allow them to be organised into the linear system of speech. Then, the lexemes, which are phonological specifications of the lemmas, are retrieved from the mental lexicon. During articulation, the motor plan for the pronunciation of the phonemes corresponding to the lexemes is created and executed. Problems can arise at any of these stages, causing speakers to interrupt their utterances with hesitations, restarts, or filled pauses (Clark & Fox Tree, 2002; Schachter, Christenfeld, Ravina, & Bilous, 1991).

When visuo-spatial information is being conveyed, additional difficulties may arise, particularly during the stage of conceptualisation. There is some debate about how visuo-spatial information is encoded and stored in the brain (see Kosslyn, 1994, for a review), but there is increasing evidence that mental representations of visuo-spatial information consist of mental images that are supported by the same brain regions involved in visual perception (Kosslyn, 2005). As analog representations of visual perceptions, these mental images afford some of the same processes that are involved in inspecting a visual image, including decomposing a complicated image into recognisable parts (Helstrup & Andersen, 1991) and reinterpreting ambiguous images in new ways (Mast & Kosslyn, 2002; Peterson, Kihlstrom, Rose, & Glisky, 1992). The organisation and reinterpretation of mental images are processes that involve a high level of executive control and mental activity, compared to more passive processes such as image storage, maintenance, and generation (Cornoldi & Vecchi, 2003). These active processes seem particularly necessary when the visuo-spatial information is being verbally described because the global image that is formed must be broken down and organised into smaller pieces that are more manageable for speaking. However, when describing information, mental resources are already being taxed by the cognitive demands of speech production. Thus, when visuo-spatial information is being conveyed in speech, the cognitive system must exert mental effort on two fronts: the effort normally required for speech production and the effort required for parsing mental images into specific parts during conceptualisation.

One way to manage the added demand of parsing images into smaller parts may be to produce representational gestures. Goldin-Meadow, Nusbaum, Kelly, and Wagner (2001) found that speakers were able to remember more information when they gestured during a secondary task than when they did not gesture during the secondary task, thus supporting the notion that gestures can reduce the cognitive load involved in explaining information. However, the explanations given during the secondary task in the Goldin-Meadow et al. (2001) paradigm were about math equations and were not highly visuo-spatial. Furthermore, the majority of gestures produced in this paradigm were deictic (i.e., points to the visually present equation), rather than representational depictions of mental images. Nevertheless, it is possible that the finding of Goldin-Meadow et al. that gestures reduce the cognitive load involved during speaking also applies to the representational gestures produced when speaking about visuo-spatial information.

More specifically, when images need to be broken down and organised for speaking, the kinesthetic and visual information provided by gestures can focus speakers' attention on a specific piece of the spatial image that needs to be described as well as help speakers understand the relationships between various pieces of the image that are crucial for an accurate description. In this way, gestures may help speakers parse a global image into individual parts that can be efficiently organised in the linear structure of speech, and in so doing, reduce cognitive load. Rather than trying to describe an image as a whole, speakers may use representational gestures as a way to break the image down into parts more manageable for speaking, as a way to conceptualise a complicated spatial image in a way conducive to speaking.

This idea that gestures aid conceptualisation for speaking was first proposed by Kita (2000) and termed the Information Packaging Hypothesis. The Information Packaging Hypothesis holds that gestures help speakers organise spatio-motoric knowledge into verbalisable forms. Representational gestures activate particular spatial or motoric features that need to be expressed, and help organise them into a sequence of discrete units for the linear system of speech production. For example, in the process of describing a child's drawing of a house, making the image of the roof with one's hands helps the speaker realise that the image can be parsed into a triangle sitting on top of a square. Conceptualising the image in terms of these smaller shapes makes speech production easier than if the image is left as a conceptual whole with no clear starting point or name for description.

This hypothesis differs from another widely cited hypothesis about the role of gestures in speech production, namely the Lexical Access Hypothesis (Chawla & Krauss, 1994; Krauss, Chen, & Gottesman, 2001; Rauscher, Krauss, & Chen, 1996). The Lexical Access Hypothesis claims that gestures play a role in formulating speech, specifically in finding words. According to the Lexical Access Hypothesis, gestures are cross-modal primes that help speakers access specific items in their mental lexicon. To return to the previous example of describing a child's drawing of a house, making the shape of the roof with one's hands actually facilitates retrieval of the word 'triangle'. Whereas the Information Packaging Hypothesis claims that gesturing during a spatial description leads to more efficient parsing of the image, the Lexical Access Hypothesis claims that gesturing primes the word for the specific image that is being gestured. According to the Information Packaging Hypothesis, gesture production should increase when conceptual demands increase (when an image is more difficult to parse); according to the Lexical Access Hypothesis, gesture production should increase when lexical demands increase (when less accessible words are produced).

Previous studies have tried to differentiate between these two hypotheses by varying conceptual difficulty without varying lexical difficulty. Toward this aim, Alibali, Kita, and Young (2000) asked children to solve a Piagetian conservation task and either explain why the two items (e.g., two balls of playdough) contained different amounts or to describe how the two items looked different. Alibali et al. (2000) limited the analysis to pairs of responses that were lexically similar across the two conditions. They found that children used more representational gestures in the explanation task than in the description task. The authors argued that 'substantive' gestures, which express physical properties of the items, were employed more frequently in the explanation task because of the increased demands involved in conceptualising what should be said. Along similar lines, Melinger and Kita (2001, in press) found that during route descriptions, adults were more likely to gesture when there was a greater choice of what to say than when there was a single obvious choice, despite the fact that the actual words spoken in both situations were nearly identical. Again, the authors argued that gestures arise as a result of taxing conceptual processes rather than lexical processes.

The previous two paradigms (Alibali et al., 2000; Melinger & Kita, 2001, in press) held lexical output constant and compared gesture rates when conceptual demands differed. These studies both found that gesture rates increased when the conceptual demands of the task increased. However, the two studies defined and manipulated conceptual difficulty somewhat differently. In Alibali et al., the increase in conceptual difficulty in the explanation task was primarily an increase in the extent to which information needed to be logically compared and integrated in the response. In Melinger and Kita, the increase in conceptual difficulty at route choice-points was primarily an increase in how difficult it was to determine the correct or most efficient route from multiple possibilities. Neither study directly addressed the specific type of conceptual difficulty of interest here: organising a complex spatial image into smaller units. The Information Packaging Hypothesis claims that representational gestures are a means of expressing spatio-motoric information so that the analytic processes of speech production can organise those ideas more effectively. This claim specifically predicts that representational gestures should occur more often when spatial information needs to be organised, a claim that has not been explicitly tested by the conceptual demands imposed in previous work.

The present experiment was designed to directly test the hypothesis that representational gestures are associated with organisational aspects of conceptualisation, rather than conceptualisation more generally. Organisational demands for conceptualisation should be greater when the spatial image being spoken about is ambiguous, because the speaker must do more work to parse it into discrete units. In the present experiment, we manipulated whether or not patterns were already chunked into units appropriately sized for speaking when they were presented to speakers. The Information Packaging Hypothesis predicts that when speakers are describing spatial information that is not easily organised or chunked, they will be more likely to produce gestures as a strategy to efficiently organise the information.

To this end, we developed a dot description task, in which participants were asked to describe patterns of dots to a listener. Patterns were created that could be conceptualised in a number of different geometric ways. For example, the pattern in Figure 1 could be conceptualised as a diamond on top of a triangle, a square with a triangle on top, two parallelograms, or a five-pointed star (to name only a few possibilities). The images in this dots-only condition are difficult to parse into discrete units for speaking because the arrays do not clearly separate into smaller parts. In contrast, when the dot patterns are displayed with lines drawn through them to guide conceptualisation (the dots-plus-shapes condition), they are much easier to parse for speaking. In the dots-plus-shapes condition, the lines connecting the dots provide speakers with a clear method for organising the information into small chunks that are manageable for the speech formulation process. In the dots-only condition, speakers must generate such a method for themselves. Because the global image of dots in the dots-only condition must be parsed into smaller units (particular shapes), the Information Packaging Hypothesis predicts that more gestures will be produced in that condition than in the dots-plus-shapes condition.

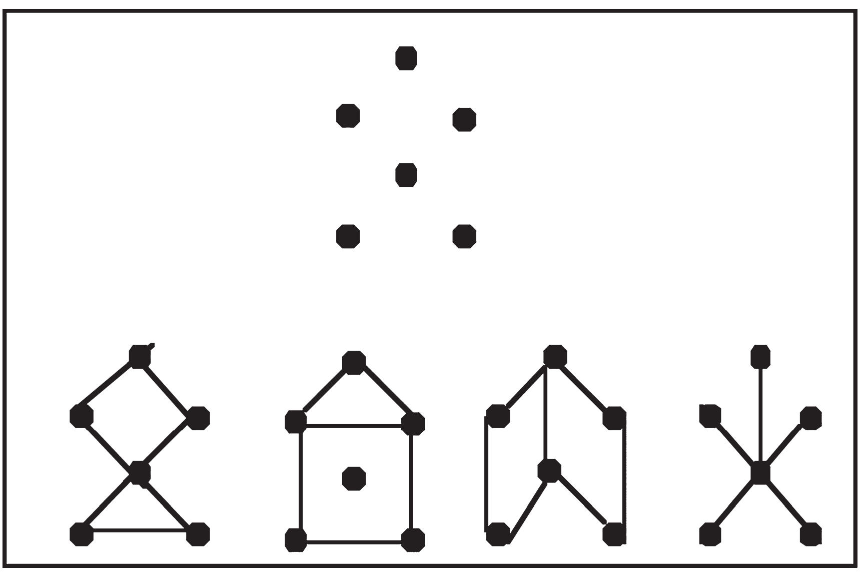

Figure 1. A sample pattern used in this experiment (top) and four possible conceptualisations. The conceptualisations are similar to stimuli in the dots-plus-shapes condition.

The Lexical Access Hypothesis would not predict this difference a priori. Although the Lexical Access Hypothesis could explain the difference expected here if it were shown that the dots-only patterns elicited more difficult lexical items, such a difference in lexical demands is not expected to exist. Speakers must access similar words (geometric shape names, spatial prepositions, and so forth) with similar time demands in both conditions. Nonetheless, the verbal output produced in the two conditions will be closely analysed to rule out the possibility that the dots-only condition, in addition to being more conceptually difficult, also required accessing more difficult lexical items.

METHOD

Participants

Participants were 26 native English speakers (22 female, 4 male)[1] recruited from the Psychology research pool at the University of Wisconsin-Madison. Data from two female participants were excluded because their posture made it difficult to see their gestures, resulting in a final sample of 24 individuals with a mean age of 18.75 years ($SD = 1.07$).

Stimuli

Six dot patterns were designed, each of which included six to nine black dots on a white background (see Appendix A). Each pattern was designed so that it did not represent the outline of any single geometric shape, but instead afforded a variety of different geometric conceptualisations (see Figure 1). In order to determine that each dots-only pattern could be conceptualised in multiple ways and to establish the most common conceptualisation for each pattern, 24 individuals described each pattern during pilot testing (see Hostetter & Alibali, 2004). Each of the six patterns elicited between 6 and 12 different geometric conceptualisations ($M = 8.33$) from the 24 pilot participants.

For each dots-only pattern, a dots-plus-shapes counterpart was created. Each dots-plus-shapes counterpart represented the most common conceptualisation given for the dots-only pattern during pilot testing. The dots-plus-shapes patterns consisted of the same black dots as the dots-only patterns, but they had lines drawn through them to indicate a particular geometric configuration (the one that had been described most often for that pattern during pilot testing). In this way, the patterns presented in the dots-plus-shapes condition indicated a clear, straightforward configuration

[1] The unequal gender distribution is representative of the distribution in the participant pool.

that would require little conceptual parsing, as the lines guided conceptualisation at the time of encoding. In contrast, the patterns in the dots-only condition were meant to be more ambiguous and to require more parsing during speech production as speakers determined an efficient way to describe them.

All stimulus patterns in both conditions were created in AppleWorks 6 and loaded into PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993). They were presented on a Macintosh Powerbook G3 laptop with a 35 cm colour screen during the experiment.

The order of presentation for the six patterns remained constant across participants. However, two condition orders were created. In one order, the first three patterns were shown as dots-only patterns and the last three as dots-plus-shapes patterns. In the second order, the first three patterns were shown as dots-plus-shapes patterns and the last three as dots-only patterns. Thus, each participant described two different sets of three patterns, one set that was dots-only and one set that was dots-plus-shapes, and the order in which the two sets were described was counterbalanced across participants.

According to image-activation accounts of gesture, representational gestures occur when images must be generated and maintained in memory. It is possible that the dots-only and dots-plus-shapes versions of patterns in the present experiment differ in how easy they are to activate in memory. To check for this possibility, we conducted a memory check of the patterns in the two conditions using a different sample of 24 participants. In this separate memory check experiment, participants viewed each pattern for 3 s and then read a short literary passage for 45 s. They then drew the dots they saw in the pattern presented earlier and answered three questions about the literary passage. We compared both the accuracy of participants' drawings as well as the length of time it took them to draw the patterns in each condition. Participants produced the same number of accurate reproductions for dots-only patterns ($M = 2.50$, $SD = 0.78$) and for dots-plus-shapes patterns ($M = 2.21$, $SD = 0.88$), $t(23) = 1.63$, $p = .12$. Similarly, there were no differences in the amount of time participants spent reproducing the dots-only ($M = 16.22$ s, $SD = 6.12$ s) and dots-plus-shapes patterns ($M = 16.73$ s, $SD = 5.60$ s), $t(23) = 0.89$, $p = .38$. This memory check suggests that the dots-only and dots-plus-shapes versions of the patterns did not differ in memory demands. Thus, any differences found in the gestures participants use when they describe the patterns cannot be explained by image-activation accounts, as activation of the pattern images appeared to be equally difficult in both conditions.

Procedure

Participants were told that the study focused on their ability to remember dot patterns presented for very short durations and to describe these patterns effectively to another participant. They were told that their descriptions of the dot patterns would be audiotaped and played later for other participants who would try to recreate the patterns based on their descriptions. In fact, a hidden video camera was focused on the participants throughout the experiment, providing a head-on view of the participants from the waist up, and no one other than the experimenters heard their descriptions. At the end of their session, participants were debriefed regarding the true purpose of the experiment and given the opportunity to have their videotape erased. All declined.

Each participant arrived individually at the testing room, and was randomly assigned to one of the two orders of condition presentation with the stipulation that after 26 participants, the orders would be equally represented. A wooden screen divided the testing room. On one side of the screen, a chair sat in front of a small table (58.5 cm H × 71 cm W × 71 cm L) where the laptop computer was situated. The participant sat in this chair, and the experimenter knelt next to the participant to give the instructions and practice trial for the experiment. During the instructions, participants viewed a sample dot pattern and heard that patterns similar to it would appear on the computer screen for a very short duration. Participants were told that sometimes the patterns would have lines drawn through them, making it pretty clear how to think about them. Other times, lines would not be present, and it would be up to the participants to mentally create the lines however they wished, as long as it was in a geometric configuration.

Example patterns and sample descriptions were given for each condition. The sample dots-plus-shapes pattern had lines drawn in to denote two geometric figures (a square and a line). The experimenter produced three scripted representational gestures during the description of this pattern: one that depicted the square, one that indicated the point on the square where the line began, and one that depicted the line itself. Similarly, during the sample description of the dots-only pattern, the experimenter described a conceptualisation that involved two geometric figures (two triangles). She again produced three representational gestures during her description: one that depicted the two triangles, one that indicated the bottom of the triangles, and one that demonstrated how the bottoms were positioned relative to each other. All gestures in both conditions were produced bimanually in the neutral space between the experimenter and participant. In this way, each participant saw three comparable representational gestures produced for the description of each type of pattern. Thus it is unlikely that any effects found are due to differences in the way the experimenter modelled the task in the two conditions.

Following the sample patterns and descriptions given by the experimenter, the participants completed a practice trial for a dots-only pattern. They received feedback on their description from the experimenter. If the participants did not convey the relationships between the dots in terms of geometric shapes and figures, the feedback emphasized the need to do so. However, in most instances, the feedback simply praised the participant and encouraged him or her to keep up the good work. All instructions and practice trials were identical regardless of which condition order the participant received.

Because it was not the purpose of this study to manipulate lexical difficulty, we attempted to make lexical access as easy as possible. Following the examples and practice trial, participants read an alphabetic list of 16 words that seemed likely to occur in descriptions of the patterns. This list included seven names of specific geometric shapes that were thought to be difficult to access (e.g., *parallelogram*, *rhombus*, *trapezoid*) as well as nine spatial terms and relational prepositions that occurred frequently during pilot testing (e.g., *bottom*, *line*, *top*). The computer displayed each word in the centre of the screen for 1200 ms, and the participants pronounced each word out loud as it appeared. The goal was to have these 16 words primed and readily accessible.

After making sure that the participant understood all of the instructions and had no further questions, the experimenter pressed 'record' on the audio-recorder and retreated to the other side of the wooden screen, where she pretended to prepare for the next part of the experiment. On the experimenter's side of the screen, a table and chair faced away from the participant, so that in addition to vision being blocked by the wooden screen, the experimenter was not even looking in the participants' general direction as they described the patterns. It is difficult to ever definitively rule out the possibility that some gestures produced by the participants were intended for communicative illustration; however, the presence of the wooden screen, the relative positions of the experimenter and participant, and the participants' naïvete regarding the hidden video camera make it highly unlikely that the participants perceived any direct visual audience for their descriptions. Thus, the gestures produced by the speakers were most likely not for direct communicative illustration. Indeed, speakers never used deictic terms to refer to their gestures ('it looked like this'), where the bulk of information was expressed in gesture but not in speech.

When participants were ready to begin the first trial, they pressed a key on the laptop keyboard. At the beginning of each trial, a single black dot appeared in the centre of the computer screen for 2 s as a signal that the stimulus pattern was about to appear. The single dot was then replaced by the first of the six dot patterns (either with or without shapes drawn in, depending on the condition order the participant was assigned to). The pattern remained on the screen for 3 s and was followed by a 1 s pause. After this brief pause, a short beep cued the participant to begin describing the pattern that had just been displayed. There was no limit on the amount of time the participants could take to describe each pattern. Pressing any key on the laptop keyboard prompted the beginning of the next trial.

Coding

Participants' descriptions were transcribed verbatim, and all accompanying hand gestures were identified. A small minority of participants gestured while the pattern was still on the screen (as though they were drawing the conceptualisation they wanted to describe with their fingers). Although interesting, such gestures were not counted in this analysis because they were not accompanied by speech; gestures were only counted if they occurred with the participant's verbal description.

Gestures were classified into two categories based on previous work (e.g., Alibali et al., 2001; McNeill, 1992): representational gestures and beats. Beats are small, motorically simple, rhythmic movements that do not seem to carry any meaning. Representational gestures are movements that enact or depict the semantic content of speech. Individual gestures were distinguished from one another by a change in hand shape and/or motion. For example, a motion straight across from left to right accompanying the words 'the bottom line' was coded as one representational gesture. If a similar movement occurred as the first motion of a sequence in which the hand moved diagonally upward and then diagonally downward without changing hand shape (to mean 'triangle'), this entire sequence was coded as one representational gesture. Gesture rates per 100 words and per minute were calculated.

Reliability

A second coder who was blind to the condition of each description coded the gestures produced in a subset of the data. The subset included one pattern from each of the 24 individuals, with equal representation of each pattern and each experimental condition. Reliability with the primary coder was 88% for identifying individual gestures from the stream of manual activity, and 92% (Cohen's $\kappa = .75$) for classifying each gesture as representational or beat ($N = 141$).

RESULTS

Analysis of speech production

Both number of words and length of time spent speaking were analysed to assure that the amount of speech produced was not different between the two conditions. A 2 (condition) × 2 (order) repeated measures ANOVA was conducted with condition as a repeated measure and number of words produced as the dependent variable. No effect of condition was found, $F(1, 22) = 0.49$, $p = .49$, $\eta_p^2 = .02$. Participants used similar numbers of words to describe the dots-plus-shapes patterns as they used to describe the dots-only patterns. An effect of order did emerge, $F(1, 22) = 4.85$, $p = .04$, $\eta_p^2 = .18$, such that participants who first described dots-plus-shapes patterns produced more words than participants who first described dots-only patterns. However, this effect was driven by one outlier who described dots-plus-shapes patterns first and produced a total number of words (722) that was more than two standard deviations ($SD = 157.41$) above the mean of the sample ($M = 335.73$). There was no interaction.

A second 2 (condition) × 2 (order) repeated measures ANOVA was conducted with condition as a repeated measure and length of time spent speaking as the dependent variable. Again, no effect of condition was found, $F(1, 22) = 0.12$, $p = .74$, $\eta_p^2 = .01$. Participants' descriptions of the dots-only patterns did not span more time than their descriptions of the dots-plus-shapes patterns. There were no effects involving order.

As a within-subjects design, this experiment could not match lexical output exactly, as participants could not be asked to describe the same pattern twice without interference from practice effects. However, because descriptions in both conditions involved similar geometric and spatial terms, we expected accessibility of the spatial words produced by speakers in each condition to be similar. Spatial words were defined as names of geometric shapes (*square*, *triangle*), locations (*top*, *bottom*), constructive verbs (*connect*, *make*), dimensional adjectives (*big*, *small*), and spatial prepositions (*under*, *next to*). There were 155 spatial words that occurred at least once in one of the two conditions. Of these 155 words, 137 occurred in the dots-only condition and 123 occurred in the dots-plus-shapes condition. One hundred and three words occurred at least once in both conditions, and they accounted for 94% of the spatial word tokens in the dots-only condition and 98% of the spatial word tokens in the dots-plus-shapes condition.

The frequency with which each spatial word occurred in the dots-only condition was strongly correlated with its frequency of occurrence in the dots-plus-shapes condition, $r(153) = .89$, $p < .001$. Because of the possibility that this correlation is being driven by one word (*dot*) that occurred extremely often in both conditions, a correlation with this word omitted was also computed. This correlation was also strong and positive, $r(152) = .88$, $p < .001$ (see Figure 2). Although lexical output could not be matched exactly, the words produced in each condition were highly similar overall.

The previous analysis considers only how often each word was produced in each condition across all speakers. However, in this within-subjects design, it seems more important to demonstrate that the accessibility of words produced in each condition was similar for each speaker. Accessibility of a particular lexical item can be estimated by how common that word is in the language (Alibali et al., 2000; Levelt, Roelofs, & Meyer, 1999). The online version of the MRC Psycholinguistic Database (Wilson, 1987) was used to assign a numerical value to each word based on its frequency of occurrence in English. High values correspond to words that occur more often (max = 69,971). The database did not include frequency information for several specific geometric terms produced in our sample (e.g., *rhombus*, *parallelogram*, *hypotenuse*, etc.). The minimum value used in the corpus (zero) was assigned to these words, which accounted for less than 10% of the data.

The average English frequency of the spatial words used to describe each pattern was calculated. Data were collapsed across patterns in each of the two conditions to produce an average English frequency for each participant's dots-only descriptions and his or her dots-plus-shapes descriptions.

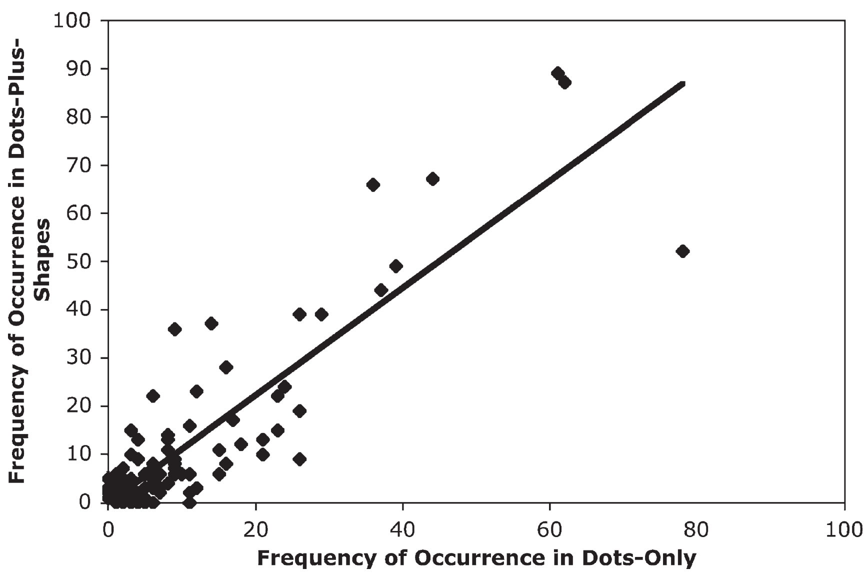

Figure 2. The number of times each of the 154 spatial terms was produced in the dots-only condition compared to the number of times it was produced in the dots-plus-shapes condition, $r(152) = .884$, $p < .001$. The word 'dot' occurred over 100 times in each condition and is omitted here, although its presence does not affect the result (see text).

This average English frequency was then used as an estimate of lexical accessibility in the two conditions. A 2 (condition) × 2 (order) ANOVA was used to determine whether the average accessibility of words differed in the two conditions. A main effect of condition was found, $F(1, 22) = 13.76$, $p = .001$, $\eta_p^2 = .38$, such that participants produced *more frequent* words in the dots-only condition ($M = 285.39$, $SE = 16.82$) than in the dots-plus-shapes condition ($M = 224.55$, $SE = 15.61$). There were no effects involving order.

This analysis suggests that participants were more likely to produce easier to access English words in the dots-only condition than in the dots-plus-shapes condition. Exactly why participants might have chosen easier words in the dots-only condition is not clear, but a possible explanation will be considered in the discussion. The Lexical Access Hypothesis predicts that gestures are produced in conjunction with difficult to access words. In the present data, more difficult to access words were produced in the dots-plus-shapes condition, leading the Lexical Access Hypothesis to predict higher gesture rates in that condition than in the dots-only condition. This is in direct contrast to the prediction made by the Information Packaging Hypothesis, namely that more gestures will be produced in the dots-only condition as participants conceptualise the ambiguous patterns.

Finally, we compared the rate of filled pauses produced in each condition. Filled pauses (e.g., um or uh) are often regarded as a sign of difficulty with speech production (Goldman-Eisler, 1958; Tannenbaum, Williams, & Hiller, 1965). A 2 (condition) × 2 (order) ANOVA was conducted, with the number of filled pauses produced per 100 words as the dependent variable. There were no effects of condition, $F(1, 22) = 0.17$, $p = .681$, $\eta_p^2 = .008$, or order, $F(1, 22) = 2.25$, $p = .148$, $\eta_p^2 = .093$. This analysis suggests that participants did not have more trouble producing speech in the dots-only condition than in the dots-plus-shapes condition. In conjunction with the previous analysis, it seems that participants had a tendency to use less frequent words when describing the dots-plus-shapes patterns than when describing the dots-only patterns; however, they did not necessarily have more trouble accessing these less frequent words. According to the Lexical Access Hypothesis, this discrepancy could be due to increased gesture production in the dots-plus-shapes condition; speakers gesture more to help themselves produce the more difficult words in that condition, thus making speech fluency comparable in the two conditions.

Analysis of gesture production

Gesture production was measured with two dependent variables: gestures per 100 words and gestures per minute. Each rate is considered separately in the following analyses. The Information Packaging Hypothesis predicts that speakers produced higher rates of representational gestures in the dots-only condition than in the dots-plus-shapes condition because of the increased conceptual demands in the dots-only condition. The Lexical Access Hypothesis predicts that because speakers produced more difficult words in the dots-plus-shapes condition, they also produced more gestures in that condition to help themselves access the difficult words.

To analyse gesture rates per 100 words, a 2 (condition: dots-only vs. dots-plus-shapes) $\times$ 2 (type of gesture: representational vs. beat) $\times$ 2 (order) ANOVA was conducted with both condition and type of gesture as repeated measures and with participant as the unit of analysis. The main effect of condition predicted by the Information Packaging Hypothesis emerged, $F(1, 22) = 12.83$, $p = .002$, $\eta_p^2 = .37$, such that participants produced higher rates of gestures per 100 words when describing the dots-only patterns than when describing the dots-plus-shapes patterns. A main effect of type of gesture emerged as well, $F(1, 22) = 26.72$, $p < .001$, $\eta_p^2 = .55$, such that representational gestures were more prevalent than beat gestures. There was also a significant interaction between condition and type of gesture, $F(1, 22) = 27.51$, $p < .001$, $\eta_p^2 = .36$. Planned comparisons revealed that although there was no significant difference across conditions for beat gestures, more representational gestures were produced when speakers were describing the dots-only patterns than when they were describing the dots-plus-shapes patterns, $t(23) = 4.35$, $p < .001$ (see Figure 3).

This analysis also revealed a marginal interaction between condition and order of presentation, $F(1, 22) = 4.18$, $p = .053$, $\eta_p^2 = .16$. Participants in both orders produced higher overall rates of gesture when describing the dots-only patterns than when describing the dots-plus-shapes patterns, but this difference was smaller for those participants who described the dots-only patterns first. When representational and beat gestures were considered separately using LSD planned comparisons, the difference in representational rates between conditions was significant for both orders ($p < .05$). Speakers produced more beat gestures when describing dots-only patterns only when the dots-only patterns were described first ($p < .05$).

To analyse gestures per minute, a 2 (condition) $\times$ 2 (type of gesture) $\times$ 2 (order) repeated measures ANOVA was done with both condition and type of gesture as repeated measures and participant as the unit of analysis. The results closely mirror those of the gestures per word analysis. The main effect of condition predicted by the Information Packaging Hypothesis was again found, $F(1, 22) = 8.37$, $p = .008$, $\eta_p^2 = .28$, such that gestures were produced more frequently in the dots-only condition than in the dots-plus-shapes condition. A main effect of type of gesture also emerged, $F(1, 22) = 27.40$, $p < .001$, $\eta_p^2 = .56$, such that representational gestures were produced more frequently than beat gestures. There was also an interaction between type of gesture and condition, $F(1, 22) = 17.13$, $p < .001$, $\eta_p^2 = .44$. More

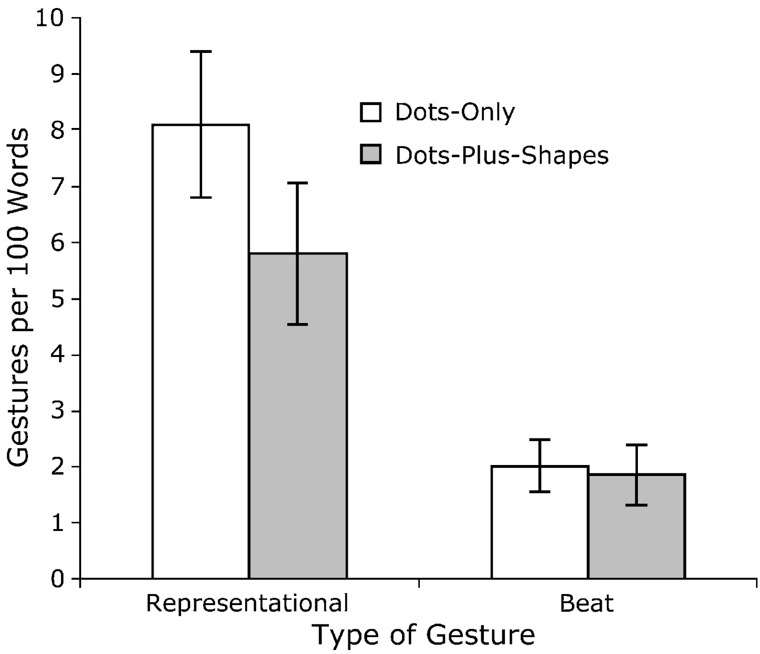

Figure 3. The mean number of representational and beat gestures per 100 words produced by participants in the dots-only and dots-plus-shapes conditions. Error bars represent standard errors, using MS_{error} for the condition × type interaction as the estimate of population variance.

representational gestures were produced per minute in the dots-only condition ($M = 11.00$, $SD = 8.78$) than in the dots-plus-shapes condition ($M = 7.85$, $SD = 8.56$), $t(23) = 3.93$, $p = .001$, while beat gestures were produced at similar rates in both conditions (dots-only: $M = 2.50$, $SD = 2.73$; dots-plus-shapes: $M = 2.50$, $SD = 3.48$), $t(23) = .001$, $p = .99$. There were no effects involving order.

DISCUSSION

The main question of interest in the present study was whether individuals would gesture more in describing patterns that are difficult to parse and organise for speaking (as in the dots-only condition) than in describing patterns that are more straightforward (as in the dots-plus-shapes condition). Speakers produced higher rates of representational gestures (both per 100 words and per minute) when describing the dots-only patterns than when describing the dots-plus-shapes patterns. At the most basic level, this finding suggests that individuals gesture more when a task is more difficult, and it is in line with previous reports (e.g., Goldin-Meadow et al., 2001) that gestures can lighten cognitive load. More specifically, however, the present data provide insight into the specific types of difficulties that give rise to gesture production, namely the conceptual difficulties involved in image organisation and interpretation.

According to the Information Packaging Hypothesis, representational gestures occur when the message being described in speech is particularly difficult to chunk into discrete units. Representational gestures are a way of breaking a complicated image that is difficult to describe holistically into component parts that can each be assigned a lemma and organised into speech. In the present manipulation, this was precisely what speakers needed to accomplish when describing the dots-only patterns. In contrast to the dots-plus-shapes patterns, the dots-only patterns could be parsed in multiple ways, and the most efficient way to parse them was not immediately apparent upon viewing the patterns. In line with the Information Packaging Hypothesis, these increased organisational demands in the dots-only condition led speakers to produce more representational gestures when describing the dots-only patterns than when describing the dots-plus-shapes patterns.

The difference in representational gesture rates in the two conditions cannot be explained by a difference in the words produced in the two conditions. The descriptions produced in the dots-only condition did not simply afford more opportunities to gesture, as they did not contain more words, nor did they span a longer time interval than the descriptions produced in the dots-plus-shapes condition. Furthermore, the words used in the dots-only condition were not less accessible than the words used in the dots-plus-shapes condition. In fact, the word frequency analysis suggests that the words produced to describe the dots-only patterns were actually *more* accessible than the words produced to describe the dots-plus-shapes patterns. This was not expected, but there is a possible explanation for why this effect occurred.

Participants had more choice about what to say when describing the dots-only patterns than when describing the dots-plus-shapes patterns. It has been shown that feedback sometimes occurs in the speech production system so that difficulty accessing a particular word can influence 'higher-order' processes, including the message itself (Kita & Özyürek, 2003; Vigliocco & Hartsuiker, 2005). In the dots-only condition, the message had more flexibility to begin with, so that if participants were experiencing lexical difficulty with their first conceptualisation of the pattern, they could generate a completely new strategy that was lexically easier. In the dots-plus-shapes condition, on the other hand, the message to be communicated was more fixed, so that the only flexibility participants had in terms of relieving lexical demands was to find a synonym for the difficult word ('rhombus' instead of 'parallelogram,' for example). However, in the lexicon of words used in this study, exact synonyms are not common. This may explain why participants had a tendency to use slightly easier words in the dots-only condition, when they could alter their message to fit the words most available to them.

If such a feedback mechanism did occur for the participants in the dots-only condition, it would seem that the increased gesture production in that condition could have been initiated as a result of lexical difficulty. However, the data do not support the conclusion that representational gestures occur solely as the result of difficulty with lexical access, as participants did not gesture as much in the dots-plus-shapes condition when lexical accessibility was even more difficult because easier words were not an option. Rather, representational gestures occur when a message is in need of alteration or reorganisation (which may be the case when lexical access for a particular item is difficult). As the participants struggled to find an alternative conceptualisation that would allow them to avoid using a particularly elusive word, they produced more representational gestures.

This alternative interpretation of the present data is also in line with the claims made by the Information Packaging Hypothesis, namely that speakers produce representational gestures when they are conceptualising a message. Speech conceptualisation encompasses a variety of processes, including parsing a global image into smaller units (the focus of the manipulation in the present experiment) or revising a message into a readily verbalisable form (as participants may have been doing in the dots-only condition), as well as processes examined in previous research: integrating information (Alibali et al., 2000) and making route decisions (Melinger & Kita, 2001, in press). In all cases, the Information Packaging Hypothesis claims that representational gestures are closely tied to the conceptual processes of generating a verbal message, rather than finding and uttering particular words.

The present manipulation did not yield a reliable effect for beat gestures. Research regarding the role of beat gestures emphasises their importance in face-to-face communication (e.g., adding emphasis to certain words, denoting aspects of the discourse structure, or acknowledging other speakers' contributions; Bavelas, Chovil, Coates, & Roe, 1995; Hadar, 1989; McNeill, 1992) rather than a more direct cognitive role. Neither condition in this experiment contained a face-to-face audience, so perhaps it is not surprising that beat gestures were relatively rare and showed no difference between conditions. More important, the Information Packaging Hypothesis claims that gestures are produced as the result of demands inherent in organising spatio-motoric ideas into a linear speech system. According to this hypothesis, it is the outward expression of spatio-motoric ideas that is helpful in organising those ideas into speech, an outward expression that is more readily accomplished by representational gestures than by beat gestures.

The Lexical Access Hypothesis would not have predicted the difference in gesture rates found in this experiment. If the increase in gesture production seen in the dots-only condition cannot be explained by differences in lexical output, the best candidate would seem to be differences in conceptualisation. A comparison of the tasks involved in the two conditions suggests that everything that must be done in the dots-only condition (remembering the patterns, chunking the dots into shapes, accessing difficult geometric shape names, describing shapes in relation to each other, etc.) is also done in the dots-plus-shapes condition, minus the demand of chunking the dots into shapes. The Information Packaging Hypothesis contends that it was this added demand of organising ambiguous spatial arrays in the dots-only condition that encouraged increased gesture production in that condition.

Speakers' tendency to produce more gestures in the dots-only condition is also difficult to explain based solely on image-activation accounts, which suggest that gestures are a means of storing and retrieving information from spatial working memory (de Ruiter, 2001; Morsella & Krauss, 2004; Wesp et al., 2001). In the present work, the dots-only versions of the patterns were not more difficult to store or retrieve than were the dots-plus-shapes versions, as verified in the memory check experiment. Rather, the conditions differed in the extent to which active processes such as organisation and interpretation were needed to describe the patterns. The present data suggest that representational gestures are associated with these more active processes of image organisation and interpretation rather than the more passive processes of image storage and maintenance.

Although the present data do not rule out the possibility that gestures, in some situations, may facilitate lexical access and memory activation, the Information Packaging Hypothesis seems to be the best explanation for the present data. The different hypotheses (Memory Activation, Lexical Access, Information Packaging) are not mutually exclusive, and it is reasonable to propose that gestures occur for a variety of reasons in different situations. The purpose of the present experiment was not to rule out these other possibilities, but rather to test the Information Packaging Hypothesis and its proposal that gestures are associated with the conceptual and organisational aspects of speaking.

The present experiment has provided insight into the cognitive situations that evoke gesture production; however, it is the claim of the Information Packaging Hypothesis that gestures actually facilitate the organisation of the speech they accompany. The present data cannot speak to whether or not gestures actually accomplish this function. However, recent thinking about both the embodied nature of cognition as well as gesture-speech synchronisation support the notion that it is possible for gestures to have a facilitative role.

Views about the embodied nature of cognition claim that action is the basic building block of cognition, and that cognition occurs primarily through simulations of real-world actions and perceptions (Barsalou, 1999; Glenberg, 1997). From such a standpoint, gesture production may be an overt way of accessing embodied knowledge (Schwartz & Black, 1999). By gesturing, speakers are able to gain a fuller appreciation of their intended meaning and are better able to express that meaning in the linear, symbolic system of language. Representational gestures make the representations themselves more vivid to the speaker and allow the speaker to more clearly see and feel the most appropriate way to think about a message or to parse an image. In the dots-only condition, where there was no clear method for organising information, evoking embodied representations through gesture was a strategy that speakers could use to organise the information that they saw and make decisions about what to mention and in what order to mention it.

The idea that gestures facilitate speech conceptualisation makes a nice story, but only if there is sufficient time between producing a gesture and producing the corresponding speech to make this facilitation possible. Gestures temporally overlap with semantically co-expressive words (McNeill & Levy, 1982; Morrel-Samuels & Krauss, 1992). However, the onset of the preparatory movement for a gesture typically precedes the onset of the semantic co-expressive words by an average of almost one second and sometimes by up to a few seconds (Butterworth & Beattie, 1978;[2] Morrel-Samuels & Krauss, 1992). Thus, it would seem that the planning of a representational gesture precedes the planning of the speech it accompanies. Current thinking in neuroscience proposes that motor plans share a neural and functional basis with motor executions and that many of the neural events involved in an overt action 'already seem to be present in the covert stages of that action' (Jeannerod, 2003, p. 140). Furthermore, it has been proposed that motor 'emulations' (e.g., motor plans) provide feedback to the 'controller' (e.g., cognitive system) that is less delayed than the feedback from overt actions (Grush, 2004). In the case of gestures, then, it may be that planning a gesture alone is sufficient for having the organisational effects claimed by the Information Packaging Hypothesis, although there may be added benefits of actually producing the gesture.

In conclusion, the present experiment has provided evidence that speakers gesture when they are faced with conceptual demands related to organising a complex spatial image into manageable pieces. Using our hands to produce aspects of the images we see in our 'mind's eye' provides a new avenue for examining the image's visuo-spatial features and relationships. Gesture, then,

[2] It is not clear whether Butterworth and Beattie measured the onset of the preparatory movement or the gestural movement proper (gesture stroke).

may be a 'hand's eye' that is not only helpful for others trying to discern our thoughts, but one that is also helpful for ourselves as we manage the cognitive demands involved in expressing those thoughts.

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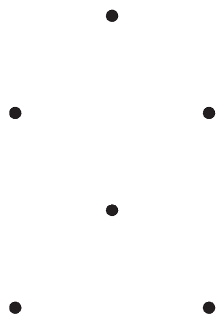
APPENDIX A

The six dot patterns used in the dots-only condition

1.



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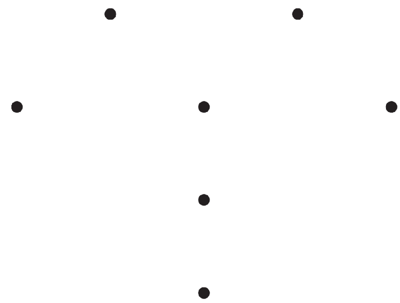

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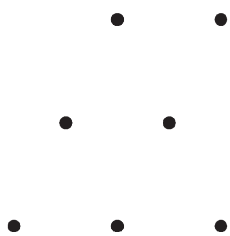

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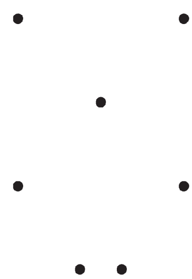

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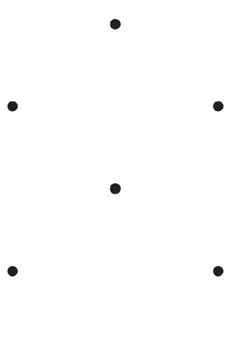

6.