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# REPORT

# Gestures convey substantive information about a child's thoughts to ordinary listeners

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## Abstract

*The gestures that spontaneously occur in communicative contexts have been shown to offer insight into a child's thoughts. The information gesture conveys about what is on a child's mind will, of course, only be accessible to a communication partner if that partner can interpret gesture. Adults were asked to observe a series of children who participated 'live' in a set of conservation tasks and gestured spontaneously while performing the tasks. Adults were able to glean substantive information from the children's gestures, information that was not found* anywhere *in their speech. 'Gesture-reading' did, however, have a cost – if gesture conveyed different information from speech, it hindered the listener's ability to identify the message in speech. Thus, ordinary listeners can and do extract information from a child's gestures, even gestures that are unedited and fleeting.*

Audio-recorders are frequently used to capture children's responses, a practice that works particularly well if all of the relevant information appears in the speech stream. However, children do more than just talk. They routinely move their hands as they speak – they gesture. Much work has shown that the gestures produced along with speech display information about the speaker's thoughts (Kendon, 1980; McNeill, 1992), even when the speaker is a child (Evans & Rubin, 1979; Perry, Church & Goldin-Meadow, 1988; Crowder & Newman, 1993).[1] Interestingly, the information conveyed in gesture does not always match the information conveyed in the accompanying speech (McNeill, 1992). For example, when asked to explain her responses to a series of conservation questions, one child highlighted the containers' heights in speech ('this one's taller than that one') while highlighting their widths in gesture (two vertical palms indicating first the narrow width of the glass and then the larger width of the dish) – she produced a gesture–speech 'mismatch' (Church & Goldin-Meadow, 1986). What makes mismatches particularly interesting is that the information conveyed in the child's gesture is often not expressed *anywhere* in that child's speech (Alibali & Goldin-Meadow, 1993; Goldin-Meadow, Alibali & Church, 1993). Gesture thus has the potential to offer a *unique* source of insight into a child's thoughts.

We ask here whether this potential is exploited in everyday interactions. It is clear that experimenters who are trained to code gesture and are armed with the advantage of instant-replay can extract substantive information from the gestures children produce. Can the ordinary listener, interacting with a child in a conversational situation, do this? The unique information children convey in their gestures is often at the cutting edge of their knowledge (Goldin-Meadow *et al.*, 1993). If adults have access to this information, they might be better able to adjust their input to a child's current and potential skills, i.e. to the child's 'zone of proximal development' (Vygotsky, 1978).

[1] The gestures that we focus on here are those McNeill (1992) calls 'representational' and Ekman and Friesen (1969, 1972) call 'illustrators'. These are the gestures that accompany speech, whose form is either iconically or metaphorically related to its referent (cf. McNeill, 1992). All of the gestures observed in this study were iconics (and deictic pointing gestures) rather than metaphorics.

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Research has explored whether untrained listeners can 'read' the spontaneous gestures children produce when those gestures convey different information from speech. In general, these studies find that listeners can glean substantive information from gesture, at least when the gestures have been pre-selected for clarity and presented more than once. For example, Goldin-Meadow, Wein and Chang (1992) asked untrained adults to view a series of videotaped vignettes of children solving conservation problems. Half of the vignettes portrayed children producing explanations in which gesture conveyed information not found in speech. The adults' responses often contained information that could *only* have come from the children's gestures, suggesting that untrained listeners can interpret gesture. This paradigm has been used with similar results in adults observing children's gestures on a math task (Alibali, Flevares & Goldin-Meadow, 1997), and in children observing other children's conservation gestures (Kelly & Church, 1997, 1998) or points (Thompson & Massaro, 1986, 1994). These studies demonstrate that a child's gestures can be interpreted when carefully selected and shown several times on videotape.

The goal of this study is twofold: (1) to explore the robustness of the ability to 'read' child gesture by examining a more naturalistic situation, one in which gesture is unedited and presented in real time; (2) to explore whether comprehension of speech is affected by the gestures that accompany it. To accomplish these goals, we chose a task known to stimulate spontaneous gesture – conservation. In addition, we needed a technique that allowed adult listeners to make judgments about a message on-line. In the Goldin-Meadow *et al.* (1992) study, the videotape was stopped after each vignette and the adult was asked to give an open-ended assessment of the child's knowledge. Because in the present study the conservation tasks were 'live', it was impossible to ask the adult for an open-ended assessment after the child completed each task. To solve this problem, we presented each adult with lists of explanations, one for each task that the child would perform; each list contained the typical explanations that children produce on this task. The adults were then asked to check off all of the explanations that the child expressed on each task. The checklist technique thus allowed adults to assess the child's performance on a task as it was being administered.

## Method

### *Participants*

Two groups of adults participated. The adults were undergraduate students at either the University of Chicago or Indiana University. Group 1 (nine females, eight males; ages 18 to 26 years, $M = 20$) observed children on videotape only. This group allowed us to test the effectiveness of the checklist technique when used in conjunction with a videotaped stimulus. Group 2 (ten females, six males; ages 18 to 23 years, $M = 20$) observed children on videotape and, one week later, in a 'live' situation. None of the adults had prior knowledge of gesture coding or sign language, and none was aware that gesture was the focus of the study. In addition, 46 children (20 females, 26 males; ages 5 to 8 years, $M = 6$) participated in a series of six conservation tasks conducted by the experimenter. Children were recruited from either the Chicago Public School District in Illinois or the Monroe County Community School District in Indiana. Subsets of these children were observed by one or more of the adults in Group 2.

### *Procedure*

#### The video task

Adults observed a videotape of 12 children (ages 5 to 8), each explaining his or her response to a Piagetian conservation task. The videotape was identical to the tape used by Goldin-Meadow *et al.* (1992), with minor alterations to improve the clarity of the sound and picture. Half of the adults saw the vignettes in one order, and half saw them in a second order. No differences were found in adult responses to the two orders and, as a result, the data were collapsed across the orders. Before viewing the videotape, each adult was familiarized with the tasks used on the tape. Props were used to explain each task.

The videotape included only children who gave nonconserving spoken explanations. For example, after the second row of checkers had been transformed (see Appendix A for a display of the checkers), one child said that the rows no longer had the same number and justified this belief by saying, 'you spread them out'. The vignettes were selected so that each spoken explanation occurred in two different contexts: (1) with gestures conveying the *same* explanation as speech (six matching vignettes); e.g. one child moved his hands as though spreading the checkers while saying 'you spread them out'; (2) with gestures conveying a *different* explanation from speech (six mismatching vignettes); e.g. while again saying 'you spread them out', a second child moved her pointing hand from each checker in one row to the corresponding checker in the other row, thus using her hands to convey an awareness of the one-to-one correspondence between the rows. All of the mismatching vignettes contained an explanation that was uniquely conveyed in gesture. The vignettes were culled from spontaneous responses children gave to a series of conservation tasks (Church, 1987). Reliability for coding the children's responses was 87%–100% agreement between two coders for isolating and describing the gestures, and 88% for coding the relationship between gestural and spoken explanations.

After each vignette was shown twice, the adult was asked to review the checklist for that vignette and check 'yes' next to all the explanations the child conveyed. Each of the 12 checklists contained four explanations. For example, for the pair of vignettes described above, the four possibilities were: (1) 'you spread one row out', (2) 'you can pair the checkers in one row with checkers in the other row', and two explanations that were culled from responses often given on this task but not produced on this particular pair of vignettes – (3) 'you could count the checkers', and (4) 'there are bigger spaces between the checkers in one row'.

Adults were told that the number of correct 'yes' responses on each list could vary from zero to four. In fact, for the checklists presented with matching vignettes, there was only one possible correct response (the explanation conveyed by the child in both speech and gesture). For the checklists presented with mismatching vignettes, there were two possible correct responses (the explanation conveyed in speech, and the explanation conveyed in gesture). On average, Group 1 checked 1.4 'yes' responses (range 0 to 4), as did Group 2.

### The naturalistic task

Adults (either alone or in groups of no more than four) watched the experimenter conduct six Piagetian tasks individually with from four to seven children. Two of the six tasks tapped number conservation, two tapped length, and two tapped liquid quantity.[2] The children's responses were recorded on videotape and later coded according to a system developed by Church and Goldin-Meadow (1986). The explanations conveyed in speech were identified by listening to the audio portion of the videotape, without reference to video. A second observer then identified the explanations conveyed in gesture by viewing the video portion of the videotape, without reference to audio. Appendix B presents a sample of explanations children commonly produce in speech and in gesture on these tasks. The relationship between the explanations conveyed in speech and gesture was then examined for each response. Each explanation in the response was classified into one of three categories: (1) an explanation that was accompanied by no gesture at all was classified as a *speech alone*; (2) an explanation that was conveyed in both speech and gesture was classified as a *gesture–speech match*; (3) an explanation that was conveyed in gesture but not in speech was classified as a *gesture–speech mismatch*; mismatches thus contained explanations that were uniquely conveyed in gesture. The children never gestured without speaking and therefore produced no instances of gesture without any speech at all.

Reliability was 89% ($N = 79$) agreement between two coders for identifying explanations conveyed in speech, 85% ($N = 55$) for identifying explanations conveyed in gesture, and 94% ($N = 79$) for determining the relationship between speech and gesture within a single response. Overall, the 46 children produced 368 explanations, 119 in which gesture matched speech, 123 in which gesture did not match speech, and 126 in which there was no gesture at all (speech alone). Each adult witnessed from 28 to 57 explanations depending upon the number of children observed.

Adults were given a checklist for each of the six tasks that the child participated in (see the example in Appendix A). The list for each task contained from six to eight explanations. The explanations were drawn from the set of explanations that children typically produce on that task (Church & Goldin-Meadow, 1986), and from the set of explanations that adults typically give when asked to describe children's responses on that task (cf. Goldin-Meadow *et al.*, 1992). Adults were asked to check or circle all of the explanations that the child conveyed. An 'other' line was included on each checklist to give adults an opportunity to add explanations. Write-in responses were rare and therefore excluded from analyses. The adults checked an average of 1.6 explanations (range 0 to 7) on each list.

Data are reported as means when the number of opportunities for an adult response was the same across the relevant comparison groups. Data are reported as percentages when the number of opportunities for an adult response differed across the groups. Percentages were subjected to a Freeman–Tukey transform prior to statistical analysis (Zar, 1984). Paired $t$ tests or an analysis of variance with repeated measures were used with two-tailed analysis.

## Results

### *Can listeners glean substantive information from gesture?*

### Gesture reading off video

We look first at the adults' ability to read gestures that have been carefully edited and presented more than

[2] See Church and Goldin-Meadow (1986) for further details on the tasks and procedures used with each child.

once. We found that adults correctly checked 'yes' on 44% of the six explanations that the children conveyed in gesture in the mismatching vignettes in Group 1, and 32% in Group 2. These explanations were conveyed uniquely in gesture by the child on the videotape. Importantly, the relatively large proportion of 'yes' responses found for these explanations was *not* due to a checking bias – adults checked 'yes' on only 13% of the 30 foils in Group 1, and 10% in Group 2. Foils were explanations that were not produced by the child on the videotape in either speech or gesture.

These observations suggest that the adults were reading the children's gestures. However, it is possible that the adults checked the explanations that the children conveyed uniquely in gesture, not because they actually read the children's gestures, but because these are the explanations that readily come to an adult's mind on tasks of this sort. To explore this possibility, we first established how often an adult checked a given explanation (e.g. one-to-one correspondence) when that explanation was *not* produced in a vignette of a number task. In other words, we established a base-rate for how often adults erroneously checked one-to-one correspondence on this particular number task. We then compared this figure with how often adults checked one-to-one correspondence when it *was* conveyed uniquely in gesture in another vignette of the same number task. We found that adults were significantly more likely to check an explanation when it was produced uniquely in gesture than when that same explanation was not produced at all on the same task (means = 2.6 (SD = 1.7) vs 0.9 (SD = 1.2), $t(16) = 4.08$, $p < 0.001$ for Group 1; means = 1.9 (SD = 1.4) vs 0.5 (SD = 0.7), $t(15) = 5.58$, $p < 0.0001$ for Group 2). On an individual level, 13 of the 17 adults in Group 1, and 13 of the 16 in Group 2, conformed to this pattern.

### Gesture reading 'live'

We turn next to the naturalistic task in which the gestures that the adults saw were fleeting and unedited. Adults in Group 2 checked an explanation on 35% of the occasions when the child produced that explanation uniquely in gesture (i.e. in a mismatching response). In contrast, adults erroneously checked explanations that the child produced in neither speech nor gesture only 7% of the time.

As in our analyses of the video data, we compared the proportion of times an adult checked a given explanation when it was produced by a child uniquely in gesture versus when that *same explanation* was not produced at all. Thus, for example, we compared how often an adult checked the one-to-one correspondence explanation on her list when the children she saw produced it in gesture (in a mismatching response) on a number task versus when the children she saw did not produce it at all on that same task. Here again, the adults were significantly more likely to check an explanation when it had appeared uniquely in gesture (in mismatches) than when it had not (37% (SD = 17) vs 7% (SD = 6); $t(15) = 7.96$ for transformed data, $p < 0.001$). On an individual level, 15 of the 16 adults in Group 2 conformed to this pattern. The group proportions are displayed in Figure 1, along with comparable data (also presented in proportions) from the video task.

Thus, in both a relatively contrived video task and a more spontaneous naturalistic task, adults were able to glean substantive information from a child's gestures, information that did not appear anywhere in that child's speech.

### *Does gesture influence a listener's ability to recognize the message conveyed in speech?*

### The video task

The 12 videotaped vignettes were selected so that we could explore whether gesture affects how accurately its accompanying speech is interpreted. In half of the vignettes gesture conveyed the same explanation as the speech it accompanied, and in half gesture conveyed a

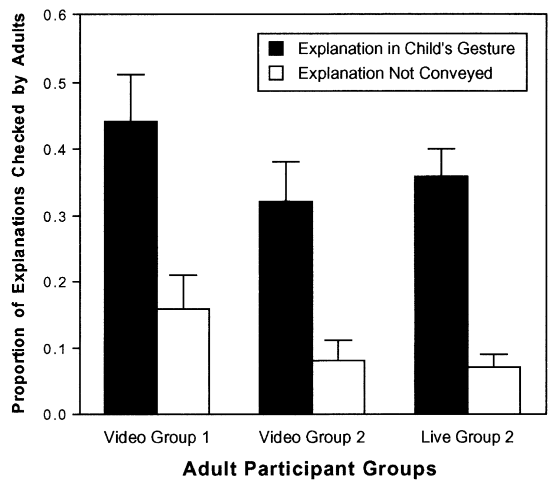



**Figure 1** *Positive responses produced by adults on explanations conveyed in gesture versus explanations not conveyed at all. The bars represent the average proportion of positive checks for an explanation that the child had produced in gesture only (black bars), compared with the proportion of positive checks for that* same explanation *when it had not been produced at all (white bars) in the two video conditions and in the 'live' condition. The error bars reflect standard errors.*

different explanation. The adults correctly identified speech in 5.8 (SD = 0.6) of the six explanations accompanied by a matching gesture, compared to 5.1 (SD = 0.9) of the six explanations accompanied by a mismatching gesture. This difference, although small, was statistically significant ($t(16) = 4.24$, $p < 0.001$). Comparable means for Group 2 were 5.7 (SD = 0.6) vs 5.3 (SD = 0.9; ($t(15) = 2.97$, $p < 0.01$).

To be certain that the differences between the two types of explanations (speech with a matching gesture versus speech with a mismatching gesture) were attributable to the presence of gesture and not to differences in the speech itself, we presented an additional group of 16 adults with only the audio portion of the stimulus tape (i.e. the picture was turned off). As expected, the differences that we hypothesized to be due to gesture disappeared – the adults were equally likely to correctly check 'yes' for the six explanations of each type when there was no picture and therefore no gesture to affect the interpretation of speech (means = 5.6 (SD = 0.6) vs 5.6 (SD = 0.5); $t(15) = 0.44$, $p > 0.66$ (n.s.)).

These results suggest that adults' ability to receive a message in speech is affected by the gestures that accompany that speech. However, it is not clear from these data whether a matching gesture *improves* the adult's ability to recognize an accompanying spoken explanation, or whether a mismatching gesture *diminishes* the adult's ability to recognize an accompanying spoken explanation. The adults in the naturalistic task observed some children producing explanations that contained speech and no gesture at all. Data from this task thus give us the opportunity to address this question.

### The naturalistic task

The proportion of spoken explanations correctly identified on the checklists differed significantly as a function of the accompanying gesture ($F(2, 15) = 6.84$ for transformed data, $p < 0.005$). As in the video task, the adults were significantly more likely to check an explanation when it appeared in speech accompanied by a matching gesture (88%, SD = 11) than when it appeared in speech accompanied by a mismatching gesture (70%, SD = 14; $p < 0.01$, Newman–Keuls).

When gesture conveys a message that matches the message conveyed in speech, it could *facilitate* a listener's ability to interpret the spoken message. To test this hypothesis, we looked at the adults' responses to the speech-alone explanations. Although the adults correctly identified spoken explanations *more* often when those explanations were accompanied by a matching gesture (88%, SD = 11) than when they were accompanied by no gesture at all (82%, SD = 15), this difference was not statistically significant.

When gesture conveys a message that does not match the message in speech, does it *hinder* a listener's ability to interpret the spoken message? The adults correctly identified spoken explanations significantly *less* often when those explanations were accompanied by a mismatching gesture (70%, SD = 14) than when they were accompanied by no gesture at all (82%, SD = 15; $p < 0.05$, Newman–Keuls). The proportions for the naturalistic task are displayed in Figure 2, along with comparable data for matching and mismatching explanations (also presented in proportions) from the video task.

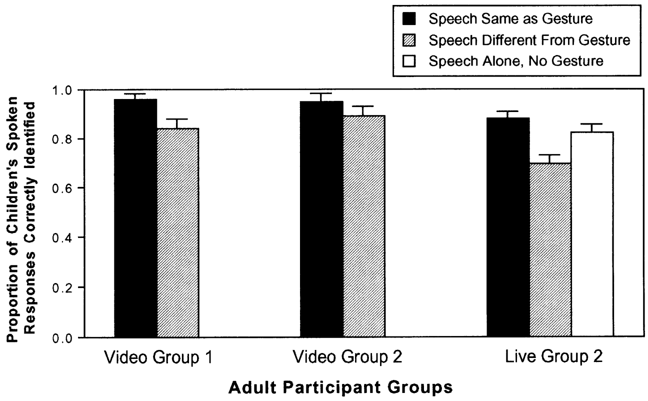



**Figure 2** *Recognition of explanations conveyed in speech as a function of the accompanying gesture in the video and 'live' conditions. The bars represent the average proportion of correct responses that adults produced for spoken explanations accompanied by gesture conveying that same explanation (black bars), spoken explanations accompanied by gesture conveying a different explanation (gray bars), and spoken explanations accompanied by no gesture at all (white bar, only for the 'live' condition). The error bars reflect standard errors.*

## Discussion

This study presents two central findings. The first is that ordinary listeners can reliably 'read' a child's gesture when it conveys different information from speech. These results extend previous studies (Goldin-Meadow *et al.*, 1992; McNeill, Cassell & McCullough, 1994; Alibali *et al.*, 1997; Kelly & Church, 1997, 1998) by demonstrating that gesture reading can occur even when gesture is unedited and fleeting, as in natural communication. Thus, listeners can, and do, utilize the unique insights offered by gesture into children's unspoken thoughts.

Even though our study was naturalistic in the sense that listeners viewed gestures on-line and without prior editing, it was nevertheless contrived in other respects. For example, the listeners were given a list which may have encouraged them to consider explanations that would not have otherwise come to mind (although, in fact, the explanations on the list were taken from explanations that adults spontaneously produce when asked to assess children's knowledge on these same tasks; cf. Goldin-Meadow *et al.*, 1992). More conservatively, our results indicate that listeners can glean meaning from spontaneous gesture when armed with a list that includes that meaning. Further work is needed to demonstrate that listeners can read gesture under even less structuring conditions.

Our second finding follows from the first. Given that a listener can extract substantive information from gesture, it is perhaps not surprising that speech can be affected by the gestural company it keeps. Interestingly, however, we found that gesture seems to hinder recognition of speech but not help it. We found no evidence that gesture *improves* a listener's ability to recognize a message produced in speech if gesture conveys the same message (see also Krauss, Morrel-Samuels & Colasante, 1991). However, we did find evidence that gesture *diminishes* a listener's ability to recognize a spoken message if gesture conveys a different message. Kelly and Church (1998) found a similar result in adults viewing pre-selected videos presented twice. Gesture thus appears to play a larger role in affecting the message listeners receive from a child's speech when the two modalities convey *different* information than when they convey the *same* information.

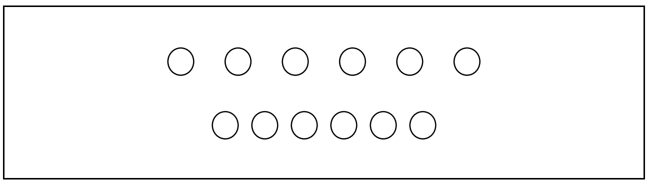
We have provided clear evidence that gesture can be read by listeners when gesture and speech convey different information. In this regard, it is important to point out that gesture–speech mismatch is a widespread phenomenon. Mismatch occurs in many tasks and over a large age range: in toddlers going through a vocabulary spurt (Gershkoff-Stowe & Smith, 1991); preschoolers explaining a game (Evans & Rubin, 1979); elementary school children explaining mathematical equations (Perry *et al.*, 1988) and seasonal change (Crowder & Newman, 1993); children and adults discussing moral dilemmas (Church, Schonert-Reichl, Goodman, Kelly & Ayman-Nolley, 1995); adolescents explaining Piagetian bending-rods tasks (Stone, Webb & Mahootian, 1991); and adults explaining gears (Perry & Elder, 1996; Schwartz & Black, 1996) and problems involving constant change (Alibali, Bassok, Olseth, Syc & Goldin-Meadow, 1995). Indeed, in our own naturalistic task, one-third of the children's conservation explanations were mismatches. The conservation tasks used in our study are, in large part, visuo-spatial. We have shown here that naive observers can 'read' mismatching gestures in a naturalistic setting when the task is one in which visuo-spatial information is important. It remains to be seen whether observers will do as well in more abstract tasks where gesture may be less transparent.

In addition to being pervasive, mismatches have special significance at certain points in the learning process for children. Children who produce many mismatches on a task are particularly likely to profit from instruction on that task (Church & Goldin-Meadow, 1986; Perry *et al.*, 1988). These children are in a transitional state and their gestures reflect their volatile cognitive status. Our findings suggest that ordinary listeners interacting with children on a daily basis have access to this important information.

We have shown that a child's gestures can convey information, not only to well-trained gesture coders who have the advantage of time and instant-replay on their side, but also to naive listeners who give little conscious attention to gesture.[3] In this way, gesture could play an indirect role in effecting cognitive change. Gesture may signal to those in a child's learning environment that a particular notion is in the child's repertoire (albeit implicitly). Listeners may then alter their behavior accordingly. They may give explicit instruction in that notion if the notion is correct or, if the notion is not on the right track, they may provide input that encourages the child to abandon the idea. If gesture does play this type of role in spontaneous interaction, children may shape their own learning environments just by moving their hands.

## Appendix A: A representative checklist used with Group 2 in the naturalistic task

Please circle or check *all* responses that you observe



[3] When debriefed after the study, most of the adults said that they had not been paying attention to the gestures produced by the children they observed.

The child indicates:

they were the same number before so they still are
they both have six
you spread one row out
you could move them back
they are different lengths
you can pair checkers in one row with checkers in the other row
there are bigger spaces between the checkers in one row
other ________________________________

## Appendix B: A sample of explanations commonly given by children in speech and in gesture on the six conservation tasks

| Type of explanation | Speech | Gesture |
|---|---|---|
| Identity by length | 'The two sticks are the same length' | Hands demarcate the endpoints of one stick and then the other stick |
| Identity by counting | 'There's 1, 2, 3, 4, 5, 6 in this row and 1, 2, 3, 4, 5, 6 in this row' | Points at each checker in one row and then the other row |
| Initial equality | 'They were the same number before so they still are' | (no gestural equivalent) |
| Reversibility | 'You could move them back' | Moves hand as though to push the row of checkers back to its original position |
| Comparison of height | 'This one's taller and this one's shorter' | Flat palm held at the height of the water in each glass |
| Comparison of orientation | 'This one's going this way and this one's going this way' | Hand sweeps along each stick, not indicating the endpoints |
| 1 vs 2 glasses | 'That's one glass and those are two' | Index finger held near the original glass, V-hand held near the two glasses |
| Transforming movement | 'You spread one row out' | Moves hand as though to push the row of checkers from its original position |

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