The effects of single and dual representations on children's gesture production

Running Head: Dual Representations

5th July 2005

Angela J. Thurnham

Karen J. Pine

School of Psychology,
University of Hertfordshire,
College Lane,
Hatfield,
Hertfordshire. AL10 9AB
UK
Tel: 01707 284000 Fax: 285073
Email: A.J.Thurnham@herts.ac.uk
K.J.Pine@herts.ac.uk

Abstract

Investigations that focus on children's hand gestures often conclude that gesture production arises as a result of having multiple representations. To date, the predictive validity of this notion has not been tested. In this study we compared the gestures of 82 five-year old children holding either a single or a dual representation. The children retold a story narrated to them, with pictures, by the experimenter. In one condition the children heard a false belief story and hence, when retelling, held two beliefs – or representations - concurrently. In the other conditions the children retold a version of the story without the false belief component and therefore held single representations. Children were four times more likely to gesture in the false belief condition than in two comparable true belief conditions, supporting the notion that gestures may function to externalise some of the child's cognitive process, particularly when they hold multiple representations.

The effects of single and dual representations on children's gesture production

Gesture is used freely by us all, spontaneously and largely without conscious awareness and is a robust phenomenon occurring across all ages and cultures. There is a growing body of literature that focuses on children's gesture production, which sees gesture as a window to the mind of the child. Goldin-Meadow (2003) suggests that while speech conforms to a codified recognition system that conveys meaning in a discrete manner, gesture is free from the grammatical constraints of language and conveys meaning globally, without words, taking advantage of visual and mimetic imagery. Gesture will often match the speech produced, but at times, for example when knowing is in transition, there will be a mismatch between speech and gesture and gesture may convey different information. Gestures produced in parallel to speech allow the child to convey more than one idea or representation at any one time, thus reflecting a more accurate picture of the child's thoughts.

Studies of children's gestures have largely focused on three major problem-solving domains: Piagetian conservation task (Church & Goldin-Meadow 1986; Goldin-Meadow, Wein & Chang, 1992), mathematical equivalence task (Alibali, Kita & Young, 2000; Goldin-Meadow, S., Nusbaum, H., Kelly, S.D., & Wagner, S. 2001; Perry, Church & Goldin-Meadow 1988) and the balance beam task (Pine, Lufkin & Messer 2004). Each has demonstrated that there is consistency in the way different children gesture when given the same task and that it is possible for independent observers to categorise the gestures produced, as representing certain variables of the problem. Studies from all three domains have found that, following instruction, those children who initially produced gesture-speech mismatches, made significantly more

progress than those whose gesture and speech matched, suggesting that gesture-speech mismatches are associated with a propensity to learn. Gesture-speech mismatches have been shown to be a reliable indicator of when a child's knowledge is in transition and can reflect when the child is entertaining more than one hypothesis, or has more than one representation of the problem. This is associated with learning because this cognitive instability often presages the acquisition of the concept. Whilst not a new idea (Piaget proposed disequilibrium theory in 1975) the finding that gestures reflect transition is a significant one.

Therefore gesture is not merely communicative but is integral to the child's cognitive processes. This is endorsed by observations of those blind from birth, who gesture spontaneously in a similar way to sighted people, even if the person they are speaking to is also blind (Iverson & Goldin-Meadow 1998). This, it is argued, is because gestures are important for the speaker. They reflect the ongoing cognitive process, assist in the conceptual packaging of information to be conveyed and can reduce cognitive load. Goldin-Meadow, Nusbaum, Kelly and Wagner (2001) tested the cognitive load hypothesis by asking children and adults to remember a list of words or letters while explaining how they solved a maths problem. It was found that significantly more words were recalled from the list when participants were allowed to gesture while solving the maths problem, than when they were told not to gesture. Gesture had the effect of reducing the cognitive demands of explanation, allowing limited resources to be used elsewhere, in this case on the memory task. In the case of the maths explanation, the task had a high spatial representation that diverted some of the burden from the verbal component. Thus, gesture and speech can be seen as complimentary ways of encoding information into a simple integrated system, each

enhancing the other for mutual benefit and lightening the cognitive burden as a result (Goldin-Meadow et al 2001).

Thus, there is a growing body of literature that shows gesture to be involved in the process of cognitive change and development in children, by providing an alternative route through which information may be channelled, or by reducing the cognitive load (Goldin-Meadow 2000; 2002). Much of this work focuses on multiple representations that accompany cognitive variability, with gesture-speech mismatches taken as evidence that children can hold more than one representation of a problem in their mind at any one time.

During times when children hold more than one representation, perhaps because they are entertaining more than one solution to a problem or activating multiple strategy choices, gesture production has been shown to increase. Studies to date have frequently invoked this dual representation explanation to account, post-hoc, for observed differences in children's gesture production during times of knowledge transition. To date, however, the predictive validity of this notion has not been tested. Therefore, in our study we set out to first *induce* dual representations in some of the children and then compare their gesture production with that of children holding a single representation. This was achieved with a false belief story that requires children to hold two representations concurrently. By asking children to retell either a false belief or a true belief story it was possible to compare gesture production under conditions of dual or single representation. The hypothesis was that children in the false belief condition would produce more gestures as a result of activating both representations concurrently, in accordance with the notion that gesture may function

to externalise some of the child's cognitive processes, particularly when multiple representations are present in the cognitive system.

The ability to understand false belief appears to develop in children between the ages of 3 to 5 years, (Gopnik & Astington 1988, Lewis et al 1994) and at around the same time in all cultures throughout the world, (Avis & Harris 1991). For a child to understand false belief, it is necessary for them to realise that someone else can form a representation of a scenario that is different from their own representation of it. This involves the child holding two representations of that event, the reality and the false belief of another. Classic examples of this understanding are demonstrated by both the 'unexpected transfer task' (Wimmer & Perner 1983; Siegal & Beattie 1991) and the 'deceptive box task' (Perner et al 1987; Gopnik & Astington 1988; Lewis & Osborne 1990).

In order to compare gesture production in children retelling a false belief story with those retelling a true belief story it was necessary to ascertain, *a priori,* the children's understanding of false belief. Children aged 5 to 6 years were recruited to the study, since children of that age are generally able to understand false belief. In order to confirm their understanding, a screening test was devised, using the standard 'deceptive box task', and wording by Lewis & Osborne (1990). Only data from children who passed the screening test was used in the main experiment.

In the main experiment the false belief story and pictures were taken from an original study by Lewis et al (1994) designed to investigate three-year olds' understanding of false belief. In the present study different versions of a wordless storybook were

created for the experimental conditions in which the children would be exposed to either single or dual representations within a story that they would then retell in their own words. On retelling, gesture production in each condition was compared. It was predicted that children given two representations, in the false belief condition, would produce more gestures than those given one representation, in the true belief condition, as a result of activating both representations concurrently.

Method

Design

A between subjects design was employed with three experimental conditions: Condition 1, the false belief; Condition 2, the true belief and Condition 3, the extended true belief. Additional independent variables included whether the child was a frequent gesturer or not, verbal fluency and gender. The dependent variable was the total number of gestures produced by children in each of the three experimental conditions. The hypothesis was that children in the false belief condition would produce more gestures as a result of activating both representations concurrently.

Participants

Eighty-four children from six Hertfordshire infant schools took part in the screening test, 40 boys and 44 girls. Two boys, both aged 5 years 7 months, did not want to take part in the main experiment. The mean ages of the remaining eighty-two children for the three experimental conditions were as follows: False belief, Condition 1 – mean 5.74 years (SD 0.27), range 5 years 4 months to 6 years 3 months; True belief, Condition 2 – mean 5.77 years (SD 0.25), range 5 years 4 months to 6 years 3 months;

Extended true belief, Condition 3 – mean 5.75 years (SD 0.29), range 5 years 4 months to 6 years 2 months.

Materials

The main experiment was divided into two phases. In phase one to screen for false belief understanding, a medium box of cereal, with the cereal removed, containing twenty buttons was used for the deceptive box test.

In phase two, the storybook task, three wordless storybooks were constructed for the three conditions: the false belief story, the true belief story and the extended true belief story. The books contained eight, five and eight pages respectively hand drawn in colour on A4 paper, spirally bound for ease of presentation by the experimenter and allowing children full use of their hands for gesturing.

Condition 1 - False Belief Story The book contained eight pages of pictures and text (see Appendix A). The story was about a girl called Suzie who left her cat in a basket in the bedroom. Whilst she was away the cat slipped out of the bedroom window and went to the kitchen. Suzie goes back to fetch her cat and is surprised to find the empty basket, thus confirming her false belief.

Condition 2 - True Belief Story This was the control condition and contained the same information as condition 1, but without the false belief component of condition 1 (see Appendix B). The story ends when Suzie successfully retrieves Whiskers from his basket, confirming Suzie's true belief that Whiskers was in the bedroom.

Condition 3 – Extended True Belief Story This was a second control with additional information, still conforming to the true belief scenario (see Appendix C). It was included as a match for the false belief condition in complexity and story length. Additional components included Suzie and Whiskers playing in the garden with a ball of red wool which became tangled up in a tree. This was to match the spatial components of the false belief task in case additional gesturing might be attributable to the story's spatial (movement) content rather than false belief.

A Panasonic VHS video camera was used to record both phases of the experiment.

Procedure

Phase 1 – Screening test

For the deceptive box test the child was shown a closed box of cereal and told that the experimenter had just been to the supermarket to buy the box. The child was then asked what they thought was inside the box. After they had given their answer, the box was opened and it was revealed that the box contained buttons and not cereal. The child was then asked 'what would the next child think was in the box before the lid was opened and they were shown what was inside?' If the child gave the correct response 'cereal' (or something similar), they undertook the next phase of the experiment straight away.

Phase 2 – Story book task

Children were randomly allocated to one of three experimental conditions. Each child was shown one set of pictures from one of three wordless picture storybooks. The story was narrated to the child page by page whilst they looked at the pictures and,

after the full story had been completed once, the whole procedure was repeated so the story was told twice, in full. The child was then encouraged to retell the story to the experimenter in their own words and in their own time, using the storybook as a prompt, page by page. If the child felt unable to continue, minimal prompting was given, such as, 'what happened next' or 'tell me what you see in the picture.'

The number of gestures was recorded for each of the three experimental conditions. A gesture was taken to be a definite iconic hand movement (McNeil 1992), over and above that seen in the general background movement of the child. Deictic gestures or self-adaptors, such as playing with the mouth, hair or hands, were not included.

Effects of frequency of gesturing and fluency of speech on gesture production

It was important to determine whether children in the false belief condition were either, naturally more frequent gesturers, or fluent speakers with more opportunity for gesturing, than those in the two true belief conditions, in order to rule out the possibility that these factors could account for the differences between the false and true belief conditions. Accordingly, the whole 5-10 minute interview was scanned for gesture production, which included the deceptive box task and the time devoted to the child, prior to the experiment, to make them feel at ease. Any gestures seen, other than those recorded in the recall phase of the experimental condition, were taken as an indication that the child was accustomed to using gesture freely. In addition, each child's verbal expression of the story was also assessed for fluency.

Results

Of the 84 participants, 82 successfully completed the deceptive box-screening task, and their data are included in the analysis below.

What constituted a gesture?

A gesture was taken to be a definite iconic hand movement (McNeil 1992), over and above that seen in the general background movement of the child. An independent rater examined a subset of the data (approximately 5%) and inter-rater reliability was 92% agreement between the two coders. Discussion resolved any differences of opinion. The remaining 95% of the data were then classified accordingly.

Number of gestures

In order to compare gesture production between the three experimental conditions the number of gestures produced when the child retold the story during the recall phase was recorded. Of a total of 76 gestures produced by 82 children in all three experimental conditions, 52 were produced in Condition 1, the false belief condition (n=28), 14 gestures were produced in Condition 2, the true belief condition (n=27), and 10 gestures were produced in Condition 3, the extended true belief condition (n=27). It can be seen from Figure 1, that, on average, children gestured more in the false belief condition 1 (1.93, s.d. 2.60) than the true belief condition 2 (0.52, s.d. 0.85) and the extended true belief condition 3 (0.37, s.d 0.88).

Insert figure 1 about here

A one-way Analysis of Variance (ANOVA) was conducted on the data, with the three experimental conditions as the independent variable and means of gesture production

for each child as the dependent variable, which showed a significant effect of condition on gesture production, $F(2, 79) = 7.32$ $p = 0.001$. Furthermore, planned contrasts revealed that gesture production in the false belief Condition 1 was significantly different from: gesture production in the true belief Condition 2, $t(30) = 2.73$ $p = 0.01$, gesture production in the true belief extended Condition 3, $t(33) = 3.00$ $p < 0.01$ and gesture production in both true belief Conditions 2 and 3, $t(33) = 2.94$ $p < 0.01$. There was no significant difference in gesture production in Conditions 2 and 3, $t(52) = 0.628$ $p > 0.05$, so simply increasing the length or complexity of the true belief storyline had no significant effect on gesture production.

Iconic gesture types

Iconic gestures were found to fall into eleven types and are detailed in Table 1, together with the conditions in which they were elicited, and their percentage occurrence across all three experimental conditions. It can be seen that four of the gesture types were seen in all three conditions, one type in two conditions, and six types in only the false belief condition. While Condition 1 elicited gestures not seen in the other two conditions (24%), the majority of gestures produced in the study (75%) occurred in more than one condition. Most of the pictures in the study elicited at least three gesture types, with the exception of picture 7 for which there were no gestures recorded; there were five gesture types recorded for picture 4 alone.

Insert table 1 about here

At what point during the retelling of the stories were gestures most likely to occur?

Analysis was made of where gestures occurred. Figure 2 shows the distribution of the 52 gestures produced in Condition 1. The majority of gestures (75%) occurred during the explanations produced relating to pictures 3-6. Pictures 4-6 were the pictures in which the child had to give the explanation of the false belief and were not found in Conditions 2 and 3. Picture 4 elicited the largest number of gestures (21%), where the cat left the bedroom via the window. No gestures accompanied the explanation to picture 7.

Insert figure 2 about here

Figure 3 shows the distribution of 14 gestures seen for the 27 participants in Condition 2, which were found to coincide mainly with pictures 1 (5 gestures, 36%), 2 (4 gestures, 29%) and 4 (3 gestures, 21%), with pictures 3 and 5 having only 1 gesture (7%) each.

Insert figure 3 *about here*

Figure 4 shows the distribution of the total of 10 gestures seen for the 27 participants in Condition 3. The majority (7 gestures, 70%) were found to accompany picture 6, where the cat was winding the wool around the tree. The other three gestures were found accompanying pictures 2, 3 and 5 (10% each).

Insert figure 4 *about here*

The five pictures that occurred in all three conditions were plotted in the same graph, (see Figure 5) and it can be seen that numbers of gestures for each of the pictures shared were largely similar for all three conditions. The exception was for picture 3 in Condition 1, the picture prior to the false belief section, where nine gestures were produced overall (17%). The child may have already been beginning to consider the dual representation at this stage and gesture production increased as a result.

Insert figure 5 *about here*

Effects of frequency, fluency and gender

Participants were randomly assigned to the three experimental conditions. However it was necessary to rule out possible confounds of frequency of gesturing, verbal fluency and gender as alternative explanations for the results seen.

Frequency

It was possible to code whether the child was a frequent gesturer or not, by examining gestures produced by the child prior to the recall phase of the experiment. Gestures observed at that time were taken as an indication that the child was accustomed to using gesture freely. Conversely, a child that was not seen to gesture during that time was classed as a non-frequent gesturer. A Chi-square analysis on all three experimental conditions did not reveal an association between whether a child was a frequent gesturer, or not, and any of the experimental conditions, χ^2 (2, N = 82) = 5.57, $p > 0.05$. However, it should be mentioned that there did appear to be an association between the false belief condition and the true belief condition, χ^2 (1, N =

55) = 5.27, $p < 0.05$, but this was not considered to be a critical weakness because there was no association between the false belief condition and the extended true belief condition, χ^2 (1, N = 55) = 0.44, $p > 0.05$.

Fluency

The child's verbal expression of the story was assessed for verbal fluency. Lewis et al (1994) coded participants into three groups: poor, average and good. These were judged by two independent examiners and were based on fluency, elaboration, clarity and coherence. Kirk and Pine (2004) devised a coding system for verbal imprecision or disfluency, which included fillers, false starts, self-reports, metacognitive comments and pauses longer than three seconds. The current study made a judgement based on the findings of the above two studies and allocated children into two groups, additionally taking into account the amount of prompting required. Two groups rated as good or average fluency were deemed sufficient, as there were no poor performers. This was expected as the material was originally designed for use on three year olds and the average age of children in this study was 5 years 7 months. Those judged as having good fluency had a sound grasp of the storyline with minimal verbal imprecision and maximum elaboration, clarity and coherence, while those judged as having average fluency got the gist of the storyline, but needed prompting, had more than one verbal disfluency and only provided the minimum amount of commentary. An independent rater examined a subset of the data (approximately 5%) and inter-rater reliability was 100% agreement between the two coders. The remaining 95 % of the data were classified accordingly.

It was expected that those who were more fluent verbally, and thus likely to say more during the recall phase, would be expected to produce more gestures than those who were less fluent, with less opportunity to gesture. It was seen from a comparison of the means across all three experimental conditions that those children whose fluency was rated as good, were nearly three times more likely to gesture than those who were rated as having average fluency. Children rated as having good fluency produced an average of 1.38 gestures (s.d. 2.34) compared to those rated as having average fluency producing an average of 0.55 gestures (s.d. 0.92). A Chi-square analysis did not reveal an association between fluency and any of the experimental conditions, χ^2 (2) = 1.21, $p > 0.05$ so it was concluded that fluent gesturers were distributed evenly across all three experimental conditions

Gender

Finally, a Chi-square analysis revealed no association between gender and any of the experimental conditions, χ^2 (2) = 0.59, $p > 0.05$

Discussion

The aim of this study was to test an inference arising from studies of gesture production in children that dual representations are responsible for differences in gesture production (Goldin-Meadow 2000; 2002), as previous work had only inferred this as a post-hoc explanation for children's gesture use. It was found that by creating for children two representations concurrently in the form of a false belief story, children were four times more likely to gesture, when they retold the story, compared to those children who were given single representations in two true belief stories.

These effects were significant, and support what had been assumed in previous work on gesture production. The findings were in accordance with the hypothesis that children in the false belief condition would produce more gestures as a result of activating both representations concurrently. Gestures function to externalise some of the child's cognitive process, particularly when multiple representations are present in the cognitive system.

In this investigation, gesture was used by children retelling a false belief story to assist with the added complexity of the dual representation. The findings add further weight to Goldin-Meadow's postulations that gesture functions to reduce cognitive load or provide an alternative route for expression through which some information can be channelled (Goldin-Meadow 2000; 2002). This was demonstrated by the fact that children were nearly four times more likely to use gesture in the false belief condition than in either of the true belief conditions. The conditions were made as comparable as possible in an attempt to manipulate only the false belief component whilst holding other variables constant. True belief Condition 2 and extended true belief Condition 3 contained the same five pictures as false belief Condition 1, but the false belief aspect was omitted by removing pictures 4-6. However, in order to rule out the possibility that length or cognitive load of the story alone affected gesture production, Condition 3 contained three new pictures with comparable movement to the pictures that had been removed, while maintaining the single representation in the story. The results showed no significant difference between gesture production in both true belief Conditions 2 and 3, and so the increased gesture production in Condition 1 was attributed to the dual representation associated with false belief. Other possible

confounds such as being a frequent gesturer, verbal fluency and gender were ruled out as possible alternative explanations.

Gesture production was seen to increase at the point of the more complex dual representation in the story; 75% of the gestures produced in Condition 1 accompanied pictures 3-6, with maximum gesture production for picture 4. Pictures 4-6 related to the false belief aspect of the story and it was likely that gesture was used here to assist the child with representing the two sides of the story by relieving the cognitive burden. Increased gesturing in conjunction with picture 3 could be attributed to the child beginning to activate and consider the dual representation. Furthermore, gesture production in all three conditions was compared by plotting the numbers of gestures for the five pictures common to all three experimental conditions on the same graph. Gesture production did not differ for the pictures shared in all three conditions, except for picture 3 in Condition 1. Therefore the increased gesture production seen in Condition 1, attributed to the dual representation, corresponded to the actual pictures 4-6 that explained the false belief aspect, as the other pictures in condition 1 did not elicit any more gestures than Conditions 2 and 3.

Qualitative differences were seen in the gestures produced across the experimental conditions, as six of the eleven gesture types produced were observed only in the false belief condition and were used specifically to help explain the false belief component of the story. Examples include children shaking their head or covering their mouth when the cat did not want to stay in the bedroom, or using a flat hand to denote the warmth and preference of the kitchen. The type of gesture used appeared to depend on the individual child rather than the picture. One child, for example, produced a total of

six gestures and was the only participant to produce ‘shivering’ and ‘sleeping’ gestures; their remaining gestures were all ‘walking finger’ gestures. Another produced a total of six gestures, but was the only participant to produce the ‘naughty mouth’ gesture, three times in three different pictures, their remaining gestures were ‘in or out’ and ‘sweeping arm’ gestures. However these six gestures constituted only 24% of the total number of gestures produced and overall, the remaining five gesture types encompassed the majority of gestures produced (75%), 70% of which occurred in all three experimental conditions. It can therefore be said that the majority of gestures produced in the false belief condition were typical of gestures produced in the other two conditions, but that the condition simply elicited more of them and at crucial times.

Were gestures used to reduce the cognitive load for the children? It is possible that they functioned to divert some of the cognitive burden from a verbal component to a spatial component (as found by Goldin-Meadow et al (2001), Alibali, Kita and Young (2000)). For example, an ‘in or out’ gesture appeared to be used to represent motion in all three conditions, without need for further elaboration, namely, the movement of the cat, the girl going out to play and turning the television on. Another example is the use of a spiral movement of the hand, which helped to describe both the wool being tangled in the tree in Condition 3 and the cat leaving through one window and returning through another. Two gesture speech mismatches were identified, demonstrating the asymmetry in the repertoires of speech and gesture (Goldin-Meadow, Alibali & Church 1993), both in Condition 1, picture 3, where the girl moved from the bedroom to the lounge to watch her favourite television program. Participant 4 gave a ‘naughty mouth’ gesture while verbally explaining that the girl

"went to watch Tweenies," implying that the cat was not complying with the girl's wishes, but not explicitly stating the fact. While participant 7 gave a 'sweeping arm' gesture, implying the cat was sleeping on the chair, which did not match the verbal statement "she went to watch her favourite program." Here, it would appear that the gestures were produced to help the children explain the multiple representations in the false belief story.

The children in this study did not produce enough gesture-speech mismatches for a valid comparison of mismatches between the true and false belief conditions. This was partly due to the task itself, as other studies that have elicited gesture-speech mismatches have utilised highly spatial tasks involving tangible materials and the explanation of physical forces, particularly in the balance beam task (Pine et al., 2004).

These findings confirm that gesture production arises when children have more than one representation, and is the first to have manipulated this experimentally. This has important implications for the role of gestures during knowledge acquisition. Since gesture is an integral part of the process of cognitive change (Goldin-Meadow 2000; 2002) schools should allow, and even actively encourage children to gesture freely in order for them to reach their full potential. This will give the child the freedom to try out new strategies in the form of gesture that are not yet ready for verbalising, or to convey representations that are not linguistically coded but are, nonetheless, part of the child's developing knowledge.

References

Alibali, M.W., Kita, S., & Young, A.J., (2000) Gesture and the process of speech production: We think, therefore we gesture. *Language and cognitive processes* 15, 593-613

Avis, J., & Harris, P., (1991) Belief-desire reasoning among Baka children: Evidence for a universal conception of mind. *Child Development* 62, 460-67

Church, R.B., & Goldin-Meadow, S., (1986) The mismatch between gesture and speech as an index of transitional knowledge. *Cognition* 23, 43-71

Goldin-Meadow, S., (2000) Beyond words: The importance of gesture to researchers and learners. *Child Development* 71, 231-239

Goldin-Meadow, S., (2002) Constructing communication by hand. *Cognitive Development* 17, 1385-1405

Goldin-Meadow, S., (2003) *Hearing Gesture: How our hands help us think.* Belknap Press, Harvard: Massachusetts

Goldin-Meadow, S., Alibali, M.W., & Church, R.B., (1993) Transitions in concept acquisition: Using the hand to read the mind. *Psychological Review* 100, 279-297

Goldin-Meadow, S., Nusbaum, H., Kelly, S.D., & Wagner, S., (2001) Explaining math: Gesturing lightens the load. *Psychological Science* 12, 516-522

Goldin-Meadow, S., Wein, D & Chang, C. (1992). Assessing knowledge through gesture: Using children's hands to read their minds. *Cognition and Instruction 9,* 201 - 219.

Gopnik, A., & Astington, J.W., (1988) Children's understanding of representational change and its relation to the understanding of false belief and the appearance-reality distinction. *Child Development* 59, 26-37

Iverson, J.M., & Goldin-Meadow, S., (1998) Why people gesture when they speak. *Nature* 396, 228

Kirk, E., & Pine, K.J., What can measures of verbal imprecision tell us about the relationship between speech and gesture. Presented at British Psychological Society Developmental Conference, Leeds, 2004.

Lewis, C., Freeman, N.H., Hagestadt, C., & Douglas, H., (1994) Narrative access and production in preschoolers' false belief reasoning. *Cognitive Development* 9, 397-424

Lewis, C., & Osborne, A., (1990) Three-year-olds' problems with false belief: Conceptual deficit or linguistic artefact? *Child Development* 61, 1514-1519

McNeil, D., (1992) *Hand and mind: What gestures reveal about thought.* Chicago: University of Chicago Press

Perner, J., Leekam, S.R., & Wimmer, H., (1987) Three-year-olds' difficulty with false Belief: The case for a conceptual deficit. *British Journal of Developmental Psychology* 5, 125-137

Perry, M., Church, R.B., & Goldin-Meadow, S., (1988) Transitional knowledge in the acquisition of concepts. *Cognitive Development* 3, 359-400

Piaget, J. (1975). *The equilibration of cognitive structures.* Chicago: University of Chicago Press

Pine, K.J., Lufkin, N., & Messer, D., (2004) More gestures than answers: Children learning about balance. *Developmental Psychology* 40(6), 1059-1067

Siegal, M., & Beattie, K., (1991) Where to look first for children's knowledge of False belief. *Cognition* 38, 1-12

Wimmer, H., & Perner, J., (1983) Beliefs about beliefs: Representation and Constraining function of wrong beliefs in young children's understanding of deception. *Cognition* 13, 103-128

Acknowledgements

Thank you to the children who took part in the study, their parents, and the teachers from the following schools for their generosity in letting us interrupt their very busy schedules: Beech Hyde School, Wheathampstead; Bernard's Heath Infants School, St. Albans; Bowmansgreen School, St. Albans; Grove Infant and Nursery School, Harpenden; High Beeches School, Harpenden; The Lea School, Harpenden.

We also wish to thank Charlie Lewis for providing photocopies of the pictures used in the original study.

Appendix A

Condition 1 False Belief Storyline (eight pictures)

As condition 2 plus three extra pictures, (4, 5, and 6) and modifications to picture 8 - Differences to condition 2 are underlined

(1) As (1) in condition 2

(2) As (2) in condition 2

(3) As (3) in condition 2

(4) But Whiskers did not want to sleep in the bedroom because it was too cold. Once Susie had gone, Whiskers got up out of his basket and climbed out through the bedroom window.

(Picture shows Whiskers climbing out of the open window).

(5) Whiskers knew it would be nice and warm in the kitchen, so he climbed in through the kitchen window.

(Picture shows Whiskers climbing in through the kitchen window).

(6) Whiskers found a nice, cosy chair in the kitchen and went to sleep.

(Picture shows Whiskers sleeping on a chair in the kitchen).

(7) As (4) in condition 2

(8) Susie went back into the bedroom, but to her surprise the cat basket was empty. Where was Whiskers?

(Picture shows Susie in the bedroom looking at the empty cat basket).

Appendix B

Condition 2 True Belief Storyline (five pictures)

(1) This is Susie and this is Susie's cat called Whiskers. They are standing in the lounge. There are two rooms either side of the television. This is the bedroom and this is the kitchen. (The rooms will be pointed out).

(Picture shows Susie holding her cat standing in front of the television in the lounge. The television is in between the bedroom and the kitchen doors).

(2) Susie carried Whiskers into the bedroom and lifted Whiskers down into his basket so that he could go to sleep.

(Picture shows Susie putting Whiskers into the basket).

(3) Susie went back into the lounge to watch the television. Her favourite program was on. (To child) What is your favourite television program? (Child's reply) Suzie is watching ---- (substitute child's favourite program)

(Picture shows Susie watching television).

(4) When (child's favourite program) was over she switched off the television and decided to go and get Whiskers so that they could play together in the garden.

(Picture shows Susie switching off the television).

(5) Susie went back into the bedroom and found Whiskers sleeping in his basket. Susie lifted Whiskers up out of the basket. 'Come on Whiskers', said Susie, 'time to play in the garden'.

(Picture shows Susie lifting Whiskers up from the basket).

Appendix C

Condition 3 Extended True Belief Storyline (eight pictures)

As condition 2 plus three extra pictures (6), (7) & (8). Same length as condition 1 – all differences from condition 2 are underlined.

(1) As (1) in condition 2

(2) As (2) in condition 2

(3) As (3) in condition 2

(4) As (4) in condition 2

(5) As (5) in condition 2

(6) Susie and Whiskers played with a big ball of red wool. Susie laughed as Whiskers chased the wool round and round a tree in the garden and the wool became all tangled up.

(Picture shows the wool wrapped around a tree).

(7) After a while it was Whiskers' dinner time so Susie left the garden and went into the kitchen to open a tin of cat food.

(Picture shows Susie putting food in Whiskers' bowl).

(8) 'Whiskers' shouted Susie, 'time for dinner'. Whiskers ran into the kitchen, straight to his bowl and began to eat his dinner. Susie and Whiskers were great friends.

(Picture shows Whiskers eating his dinner).

Figure 1 Showing mean gesture production per child in false belief Condition 1, true belief Condition 2 and extended true belief Condition 3

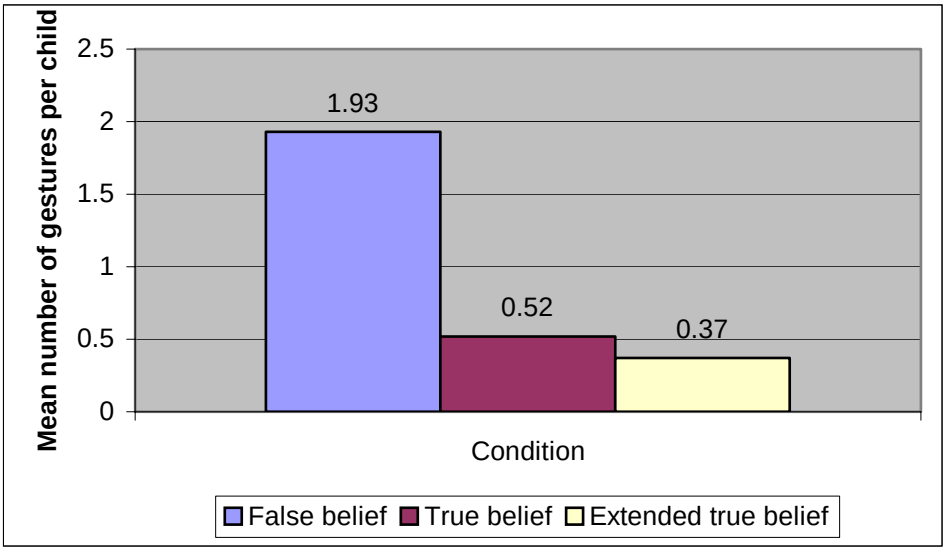

Figure 2 Showing distribution of gestures across pictures in the false belief condition

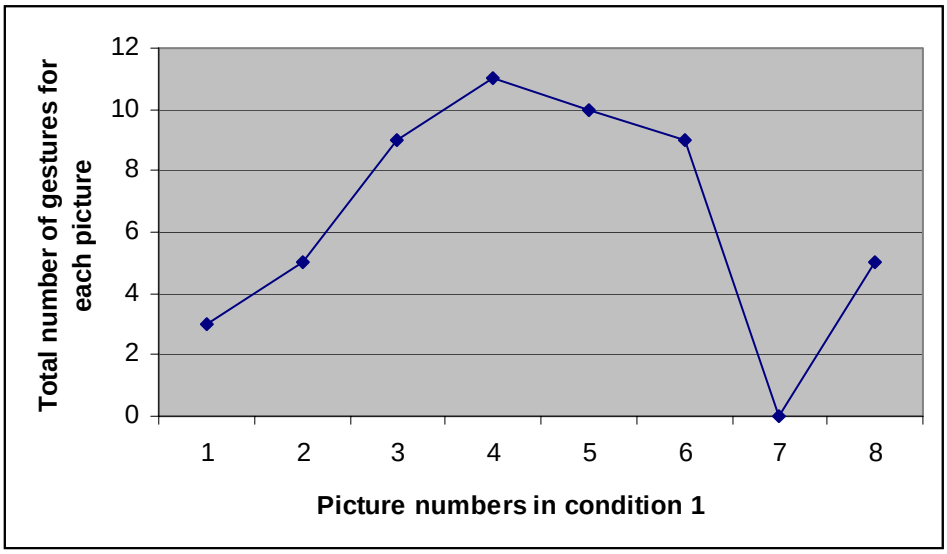

Figure 3 Showing distribution of gestures across pictures in the true belief condition

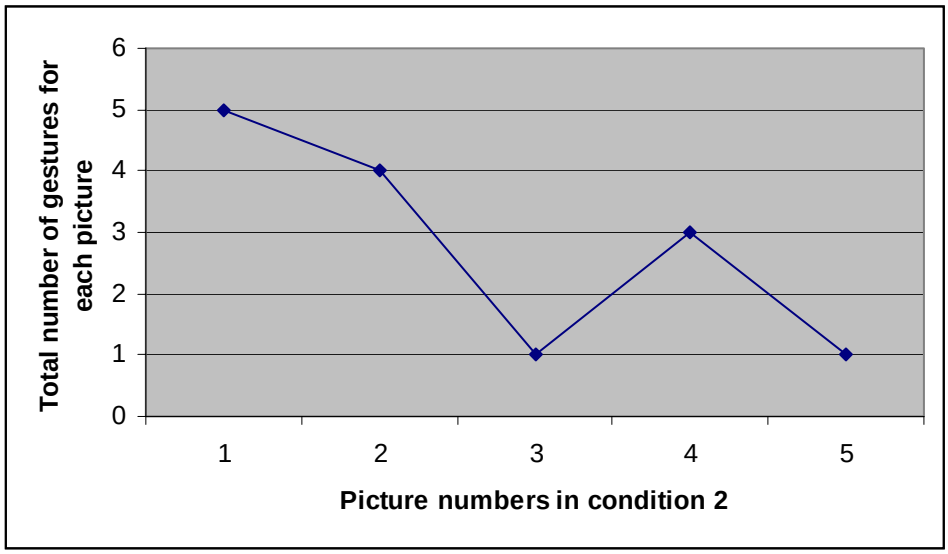

Figure 4 Showing distribution of gestures across pictures in the extended true belief condition

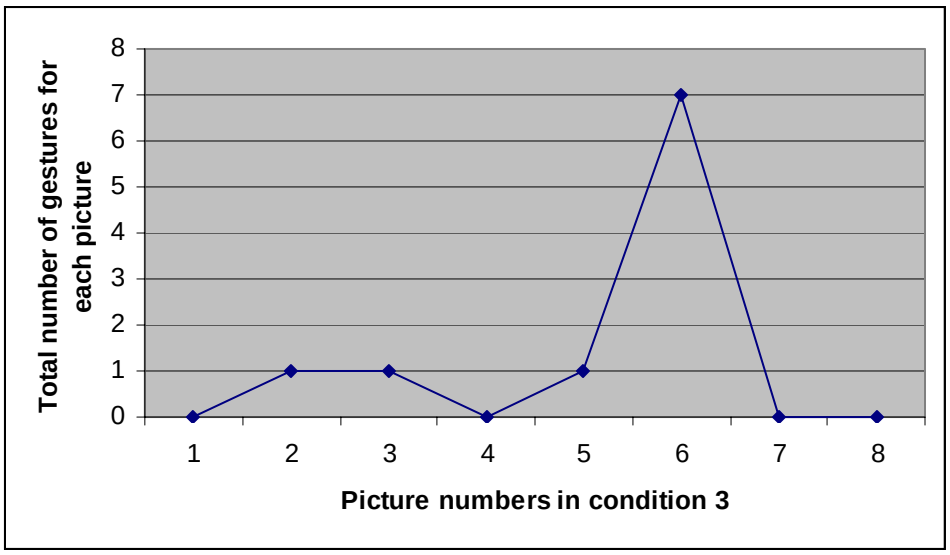

Figure 5 Showing distribution of gestures across only those five pictures appearing in all three conditions (NB Condition 1, false belief – actual pictures 1, 2, 3, 7 and 8. Condition 2, true belief – actual pictures 1, 2, 3, 4, and 5. Condition 3, extended true belief – actual pictures 1, 2, 3, 4 and 5)

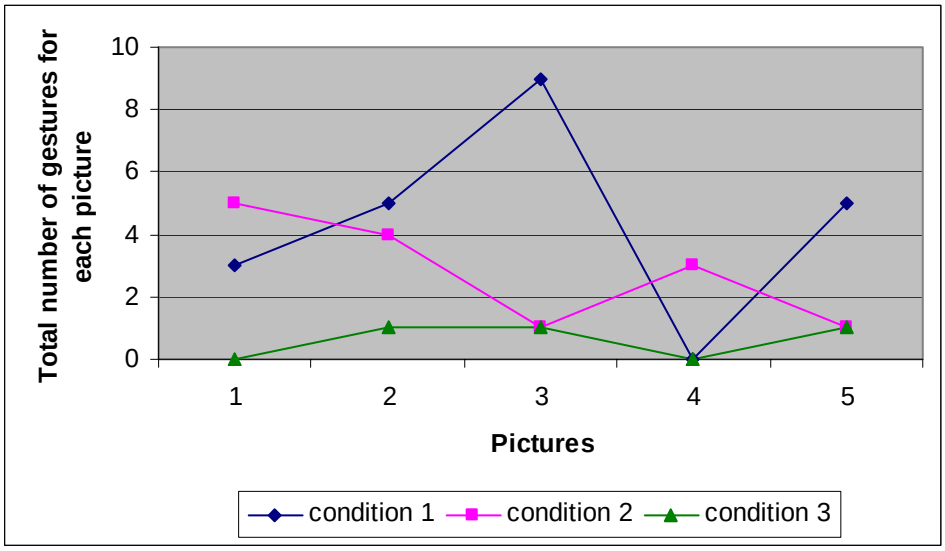

Table 1
Frequency and type of iconic gestures seen across all three experimental conditions.

Gesture Name	Occurrence	Description (condition)	Condition
'in' or 'out'	46%	Motioning with a hand, fist, arm or finger(s) the cats movements (1), going out to play (3) and general movements, e.g., turning TV on and putting cat in basket (1, 2, 3)	1, 2, 3
walking fingers	13%	First two fingers on same hand in walking motion indicating movement of cat	1
sweeping flat hand	11%	Often accompanied reference to the cat 'sleeping on the chair' where it was 'nice and warm' (1) or putting the cat to sleep (1, 2, 3)	1, 2, 3
two rooms	8%	Used two fingers on the same hand to differentiate the two rooms (1, 2, 3) - not deictic	1, 2, 3
tapping (table or other hand)	5%	Symbolised turning the television on or off (1, 2, 3) and used emphatically, e.g., when the cat did not want to sleep in the basket (1)	1, 2, 3
spiral movement of the hand	5%	Helped to explain the cat going in one window and out of the other (1) or the wool being wrapped around the tree (3)	1, 3
empty hands	4%	Lifted both palms upwards to show the cat was not in the basket	1
naughty mouth	4%	Covered hands with mouth, signifying that the cat was naughty	1
shake of head or a shrug	1%	Indicated the cat did not want to do something	1
shivering	1%	Denoted the 'cold' kitchen	1
sleeping	1%	Hands placed at side of head, palms together to signify 'sleep'	1