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Gesture production and comprehension in children with Specific Language Impairment (SLI)

Abstract

Children with SLI have difficulties with spoken language. However some recent research suggests that these impairments reflect underlying cognitive limitations. Studying gesture may inform us clinically and theoretically about the nature of the association between language and cognition. Twenty children with SLI and 19 typically developing (TD) peers were assessed on a novel measure of gesture production. Children were also assessed for sentence comprehension errors in a speech-gesture integration task. Children with SLI performed equally to peers on gesture production but performed less well when comprehending integrated speech and gesture. Error patterns revealed a significant group interaction: Children with SLI made more gesture-based errors, whilst TD-children made semantically-based ones. Children with SLI accessed and produced lexically encoded gestures despite having impaired spoken vocabulary and this group also showed stronger associations between gesture and language than TD-children. When SLI comprehension breaks down, gesture may be relied on over speech, whilst TD-children have a preference for spoken cues. The findings suggest that for children with SLI, gesture-scaffolds are still more related to language development than for TD peers who have out-grown earlier reliance on gestures. Future clinical implications may include standardised assessment of symbolic gesture and classroom based gesture-support for clinical groups.

Introduction

Non-verbal forms of communication are of much interest in the field of developmental disorders, especially disorders where communication is a primary diagnostic feature. Increased understanding about complimentary communication systems used alongside spoken language may not only inform intervention and educational practices, but also theoretical knowledge about the mechanisms underlying both atypical and typical communication. This study focuses on a group with Specific Language Impairment (SLI). This disorder is thought to affect around 7% of children (Tomblin et al, 1997) and is defined as impaired language in the presence of normal non-verbal cognitive ability.

The non-verbal communication of children with SLI is of interest for two reasons: Firstly, this group make up a substantial proportion of children with additional educational needs and children from this population are often placed within regular classrooms (Conti-Ramsden & Botting, 2000). Yet traditionally the majority of the curriculum, especially beyond Key Stage 1 (age 7-8 years), is accessed verbally through oral or written language. Alternative, non-verbal means of supporting children educationally are therefore needed, and in order to provide these, information is needed as to when and how they are able to use different aspects of symbolic communication, including gesture, to aid learning (Goldin-Meadow, Cook & Mitchell, 2009). For example, teachers may be able to use more gesture in teaching (e.g., Alibali & Nathan, 2007) to support this verbal approach. Thus there is a clinical motivation for understanding non-verbal strengths and weaknesses in atypical populations, beyond the pre-verbal stage.

Second, the gestural abilities of children with SLI are of interest in a more theoretical sense. Children with specific language difficulties have previously been highlighted in some studies as an example of clear dissociation between language skills and other cognitive processes (e.g. van der Lely, Rosen & McClelland, 1998), suggesting that language and conceptual knowledge are distinct systems. However, in recent years, this distinction has become considerably less clear-cut with numerous studies now suggesting (specific) cognitive impairment in this group (e.g., Bavin et al, 2005; Hick, Botting & Conti-Ramsden, 2005), less well developed conceptual knowledge (McGregor, Newman, Reilly & Capone, 2002) as well as increased lag in some aspects of cognitive development over time (Botting, 2005). Gesture may represent one way of exploring the relationship between verbal and non-verbal skill.

Gesture in typical development

The concept of gesture is fairly wide. It includes symbolic or pantomime gesture used in the absence of speech, co-speech gesture where the hands and the mouth contribute to the overall meaning of a message, deictic pointing, culturally bound emblems such as the ‘ok’ gesture and lastly ‘beat’ gestures which appear to mark emphasis (McNeill, 2000). In typical language development much research highlights the importance of gesture in linguistic and cognitive progression. Recently the role of gesture as a bootstrap for both linguistic and cognitive development has been highlighted (Goldin-Meadow, 2003). In production, gestures outnumber words in one year old normally developing children and many children show a strong preference for gestural over verbal communication in their spontaneous interactions, with gesture predicting subsequent attainment of language milestones by the child (Volterra, Caselli, Capirci & Pizzuto, 2005). Additionally some research suggests that teaching typically-developing children to gesture has positive effects on vocabulary development (Capirci, Cattani, Rossini & Volterra, 1998).

It has been suggested that gestures function as lexical place fillers in young TD children until they are gradually replaced by words (Stefanini, Caselli & Volterra, 2007). For example, young children sometimes achieve more complex communicative 'utterances' first by using a 'speech+gesture' strategy (e.g., mummy + ball gesture to indicate 'mummy give me the ball') and this has also been shown to be the case in gestures accompanying speech in children with SLI (Blake, Myszczyszyn, Jokel & Bebiroglu , 2008). But by 28 months children prefer verbal to gestural expression, expecting a spoken label to reference objects and their categories (Namy & Waxman, 1998). Presumably gestures outlive their usefulness as the child's linguistic system becomes more complex and more able to encode richer semantic contrasts than those offered by holistic gestures. As children grow older, the relationship between gesture and language becomes more complex and less direct, with the role of gesture varying according to the language used and the goodness of fit between gesture and speech (McNeil, Alibali & Evans, 2000). There has been less research on gesture comprehension than production. Wagner and Goldin-Meadow (2006) reported that children's comprehension of words was even more correlated with their appreciation of gesture. Gesture is more likely to facilitate comprehension when it scaffolds or reinforces the message and when that message is more complex (McNeill, Alibali & Evans, 2000).

<u>Gesture in children with language impairment</u>

Research on how language impaired children use and understand gesture has often looked at how they deal with symbolic or representational gestures e.g. those that depict 'combing', 'opening an umbrella', 'phoning' or 'swimming' and this literature has painted a mixed picture concerning how well they are produced or understood depending on the type of task used and the age of the children. Some studies show that this group have motor difficulties related to gesture at least when these symbolic or pantomime gestures are considered. For example, Hill (1998) tested praxis in 20 children with language impairment (LI) using solicited copying of both non-symbolic hand gestures (pat the table then twist the arm at the elbow), as well as symbolic gestures (hand and arm movements to indicate an action e.g. riding a bike). Despite the children having no reported motor problems prior to this study over half the children (11) had a lower than normal performance on this task. Hill (1998) argued that the quality of representational gestures produced by children with SLI was immature compared with the TD children. Therefore for this type of task, gesture production in this group was impaired when spoken language was impaired. In another more recent imitation study, Marton (2009) used a variety of motor imitation tasks with children who had SLI, including tests of posture, hand movement and tasks relying on kinaesthetic awareness. She replicated the general finding of Hill, showing that children with SLI were poorer at these tasks than typical peers even when IQ was controlled. Although these studies both found a link between SLI, imitation and language none of these tasks measured communicative gesture and instead largely investigated the motor and imitation skills of the individuals.

Other research suggests that communicative gesture and linguistic abilities can be more independent in children with LI and even that gesture may act in a compensatory way in comprehension, but again the literature is equivocal. Evans, Alibali & McNeill (2001) concluded that older children (7-9 years olds) with SLI expressed more sophisticated knowledge about events in a Piagetian conservation task in their gesture than cognitively matched TD children. The children with SLI more often expressed information in gesture that was not present in their speech and distributed more information across speech and gesture than solely in speech (Evans et al, 2001). However, in a later study by the same team, there appeared to be no gesture differences between children with SLI and either age matched or task matched peers (Mainela-Arnold et al, 2006). This was despite the fact that children with SLI were poorer at the conservation tasks. Further mixed evidence comes from an early study by Thal et al (1991) who measured use of communicative gestures in a group of children with delayed onset of expressive oral vocabulary (late talkers) compared with language use among typical-language-matched and age-matched controls. Initially, analyses appeared to reveal that late talkers used significantly more communicative gestures and for a greater variety of communicative functions than did language-matched controls. However, a follow-up revealed that 4 of the late talkers remained delayed (truly delayed late talkers) and 6 caught up (late bloomers). Only the late bloomers used more communicative gestures than language-matched controls. This may imply that for those who went on to develop a language disorder, some non-verbal communication processes were also impaired. Thus, so far, the findings as to whether symbolic gesture is impaired or relatively spared in children with SLI appear to be mixed. This may be due to different methods used, a concentration on gesture imitation or production, rather than comprehension and a preponderance of studies focussing on very young, often pre-school children.

The lack of standardised assessments for gesture in children also means that comparisons across studies are problematic, even though theorists have used these data to argue different positions on the relationship between gesture and language (e.g., McNeill, 2000; Kita & Özyürek, 2003). One reason for this lack of tasks, especially in clinical populations, may be due to difficulties involved in gaining good reliability for observations of gesture production and therefore questionnaires or observation techniques have been used instead. However these methods have their own limitations including the time to collect gesture information and respondent bias. Thus the assessment of gesture ability in this group using a more formal test procedure would be an advantage for future research.

The present study aims to examine both the comprehension and production of symbolic gesture in school age children with SLI and age-matched peers, using two novel assessments. Specifically it aims to:

a) Compare typical and atypical language groups on ability to produce novel (non-imitated) symbolic gestures

b) Compare typical and atypical language groups on the ability to comprehend integrated words and gesture

c) Examine the types of error patterns produced by each group, when integration of words and gesture is not achieved – that is do children with SLI rely more heavily on gestural or spoken cues when selecting an incorrect answer.

d) Examine relationships between gesture tasks and vocabulary, motor skill and non-verbal cognition in each group

Based on the observational studies by Thal showing that younger 'late-talkers' do not show complete language and gesture catch up, we predict that children with SLI will show poorer gesture production ability than peers. We also hypothesise that when attempting to comprehend a sentence in which both gesture and speech cues are needed, the children with SLI will perform more poorly. However of more interest is which cues children with SLI will use on error trials. Here we predict that children with SLI will attend to gestural information in preference to linguistic cues.

Method

Participants

For the purposes of this study, gesture data from 39 children was obtained: 20 with specific language impairment (SLI); 19 age-matched children with typical language development. The children with SLI were aged between 4;3 and 7;4 years of age (mean 5;7, SD=9mths). No significant difference was found between the groups on age ($F(1,37)=0.95$, $p=0.34$). There were 16 boys and 4 girls. The TD children were aged between 4;7 and 6;7 mean TD =5;8, SD=8mths) and comprised 8 boys and 11 girls. More children completed the comprehension task than the production task. Three children had no production task data: one child from each group produced no gestures, and for one further child with SLI, technical error resulted in no video-taped data to analyse. The children were recruited to the original study from five mainstream primary schools with which the researchers had previously established relationships. The children with SLI had received their diagnosis from a Speech and Language Therapist prior to entering the study and all but one (who had only expressive impairments) had expressive and receptive difficulties. None of the children had marked pragmatic difficulties according to therapists. The children with typically developing language were recruited from within the same schools. Post hoc analysis showed non-significant differences between the SLI and TD groups' non-verbal raw score and a fine motor control task (see below). As expected, significant differences were seen on both vocabulary tasks. See table 1 for details.

[Table 1 about here]

Profile tasks

Raven's Coloured Matrices (Raven, 1997): This non-verbal cognition test presents the child with a series of patterns from which a 'piece' is 'missing'. The child is instructed to look very hard at the pattern and select (from six alternative 'pieces' printed below the pattern) the one and only piece that can complete the pattern. The test is split into three sets of twelve patterns each.

Expressive One Word Picture Vocabulary Test (EOWPVT; Brownwell, 2000): Children are shown a series of colour pictures of objects, actions or concepts and asked to name them. The items become increasingly more difficult. Again, raw scores are used in analysis in the present study.

British Picture Vocabulary Scale (BPVS-II; Dunn, Dunn, Whetton & Burley, 1998): This is a widely used standardised test of vocabulary comprehension. Children are shown four line drawings and asked to choose the one which best illustrates a word spoken by the assessor. The vocabulary is given in blocks of twelve which become progressively more difficult, and children must score more than 4 to continue to the next block. Raw scores will be used here.

Bead threading: This task has been widely used to investigate fine motor control in young children. (E.g., Ramus, Pidgeon & Frith, 2003). Children were given a shoe lace and 15 wooden beads and were asked to thread the beads onto the string as quickly as possible. Performance was timed, with the task being discontinued after 10 minutes.

Gesture production task

Development

Twenty pictures were selected from the Microsoft online clip-art gallery, falling into five separate categories; the weather (2 pictures: snow and wind), food (3 pictures: hamburger, banana and milkshake), sport (5 pictures: bowling, boxing, tennis, karate, and javelin throwing), animals (5 pictures: spider, horse, gorilla, bird, crab), and clothes (5 pictures: glasses, gloves, jumper, scarf, hat). See Appendix 1 for items. [1] The pictures chosen included a range of low-high frequency words that denoted people, objects or animals. They were all items that could be described verbally using concrete nouns. However it is worth noting here that gestural depiction of nouns is often 'action' based – e.g. banana is gestured as *peeling* a banana. However, no verbal production of the item was required in this task: thus children needed to know what the item was, rather than have a functional label for it. To the authors' knowledge no database of symbolic gesture acquisition exists. The pictures were presented using Microsoft Powerpoint. All of the children were presented the stimuli in the same order which was pseudo-randomly generated to avoid long sequences of words from the same category. The full set of pictures is available from the authors on request.

Administration

A short training phase was administered in order to familiarise the child with the experimental procedure. The experimenter (the second author) gestured a series of objects not included in the main study, e.g. snake and telephone, and the child was asked to guess what they were. Then the experimenter said "Now you have to show me with your hands." He then put on some headphones saying "I'm going to put on some headphones so that I can't hear you." If the child tried to talk with the experimenter from then onwards he would reply "I can't hear you!" and prompted "show me with your hands". The children were **not** requested to be silent while gesturing in case this changed the process of accessing the concept and producing the gesture (Goldin-Meadow et al, 2006) and were therefore allowed to speak whilst gesturing. The task employed an information-gap paradigm whereby a laptop screen was set up facing the child, but out of view of the experimenter. The child was presented the target pictures one by one in a fixed order, and was required to describe each picture using gesture. All of the children's responses were video recorded for later analysis.

[1] A possible issue was that although all these pictures could be described in concrete nouns, some of them conveyed abstract entities that cannot be directly manipulated. We did not control the numbers of pictures in different categories of objects. However, to the authors' knowledge, there is currently no research examining gestural interpretation of spoken words from different categories.

Scoring

The scoring of the video data had two parts: a) Gesture production score b) Gesture identification.

Gesture production score:
Two final year BSc speech therapy students rated the gestures of each child using a 1-5 rating system where 1 was "not related at all to target" and 5 was "perfectly understandable from gesture". Neither rater had tested the children originally, and both were therefore blind to group status. All available gesture production data was rated (see participants section for children without data). A gesture production score was created by summing scores across items.

Gesture identification:
A second stage of scoring, involved five final year BSc students of speech and language therapy. A random selection of 98 (12%) of gestured *items* were rated. The raters were asked to identify what target each child was attempting to gesture from a choice of 4. In order to reduce bias, the video data of each child was presented in a randomised order. For each gesture clip seen, 4 different pictures were given to the rater. These included the target, an item that would be described with a visually related gesture, a semantically related picture and an unrelated picture. There was no audio input provided to the scorers as the participants sometimes verbally labelled the target while gesturing.

<u>Gesture comprehension task</u>

Development

The task was a novel "speech + gesture = utterance" paradigm created by Cocks et al (2009) based on behaviour observed in typically developing children during early development and children with SLI (Blake et al, 2008). Each of the 26 items consisted of a digitized video clip of the 4th author presenting a spoken sentence frame, with the gesture produced in place of the final word in the sentence, e.g. "In the zoo I saw a + TIGER GESTURE". The child was then asked to identify the missing word from 4 choices. The spoken part of the item, and the gesture part of the item were designed to be ambiguous if processed separately. Thus both the spoken language and the gesture needed integrating in order for participants to pick the correct item from 4 presented. As well as the target item, there were three kinds of distracters: A gesture distractor, which consisted of a picture which did not fit the linguistic context but could be described using the stimulus gesture. For the above example, the gesture distractor picture consisted of a monster which could also be represented using the tiger gesture; A semantic distractor, which fitted the linguistic context but not the gesture, e.g. in this instance a hippo; and an unrelated distractor was syntactically appropriate, but semantically odd, e.g. a sponge. Note that the child was asked to point to the correct meaning of the gesture - no verbal 'naming' was required by the child

Twenty six items containing symbolic gestures were used. In total, 18 of the gestures corresponded to nouns, 4 of them corresponded to verbs, or noun-phrases denoting actions, and 4 gestures corresponded to adjectives. The number of items in each category was too small to perform a cross-type analysis. The items were presented on a laptop computer (see Appendix for items). Although no verbal output was required from the children, the speech element of the task clearly requires verbal processing. Because of this, the expectation was that children with SLI would perform more poorly in selecting the correct item. However, the interesting question would be which distractor children choose when unable to process both gesture and speech: would children with SLI be more likely to use spoken or gestural information when selecting an erroneous response?

Administration

Each stimulus item was preceded by a randomly chosen animated display, e.g. fireworks, or an animated cartoon character bouncing across the screen, in order to focus the child's attention on the screen. Then the item's video clip was played. The picture responses were presented on a 2x2 grid on the screen, with the position of each type of item (target plus three kinds of distractor) randomised. The child chose the target by pointing at one of the four choices, and their response was noted on paper by the experimenter. Clarification requests were made, e.g. "Which picture did you point to?" if the child pointed in an ambiguous direction.

General Procedure

Children were seen and assessed in a single session. Testing took place in a quiet room or area within the school. Tasks were administered in a set order for all children. Normal school breaks were provided. Written parental permission to participate in the original and all connected research, as well as specifically to video recording was obtained from all participants' guardians prior to recruitment. The City University Senate Ethics Committee approved the project and The British Psychological Society's guidelines were followed at all times.

Results

Production task

Task characteristics

Initially, the correlations between raters for each of the 20 gestures ranged from 0.2 to 0.9, with a mean correlation of 0.7. Items which correlated at less than 0.5 (following Cohen, 1988, guidelines for large correlations >0.5) were then removed: there were 4 of these (horse, gloves, sweater and snow). When a summed 'gesture production score' was calculated for each child, the revised scale of 16 gestures yielded a bivariate correlation between raters of 0.82 ($p<0.001$) and an intraclass reliability coefficient of 0.90. Internal consistency was also good with Cronenbach's alpha = 0.90. Data from both groups showed normal distributions across the range. See table 2 for range, skewness and kurtosis information. Developmental trends were examined through correlations between age and performance and were significant when both groups were combined ($r(36)=0.41$, $p=0.01$). When groups were examined separately, the SLI group appeared to show stronger associations ($r(18)=0.50$, $p=0.025$) than the TD group ($r(18)=0.07$, $p=0.8$). This may be partly due to the slightly narrower range of ages in the TD group.

[table 2 about here]

Comparisons between groups

Four separate group comparisons were made.

i. Firstly each item was compared on gesture production score across SLI and TD groups. Only 2 items showed significantly different scores between groups: hat and hamburger. Given the number of comparisons made here, we do not feel these small differences are important.

ii. Second, the total gesture production score was compared. Not surprisingly given the item results above, no difference was found between totaled gesture production scores. Table 3 shows the details.

iii. The third analysis concerned how accurately independent raters with a clinical knowledge of SLI could guess the child's gesture. The raters were able to guess the majority of gestures regardless of diagnosis (mean = 82/98; sd=7; 83.9%,) and there was no difference in the accuracy of guessing gestures from the different groups. The number of gestures guessed correctly ranged from 74/98 (75.5%) to 92/98 (93.9%).

There were no gender differences in the gesture scores, using any analysis, either both groups together or separately.

[table 3 about here]

<u>Comprehension task</u>

Task characteristics

The comprehension task also showed a good range of scores in each group (see table 4). Developmental trends were seen in the group as a whole ($r(39)=0.57$, $p<0.001$) and also in both the SLI and TD groups separately (SLI: $r(20)=0.47$, $p=0.034$; TD: $r(19)=0.67$, $p=0.002$). See table 2 for skewness and kurtosis information.

Comparisons between groups

Recall that this task required children to integrate both speech and gesture in order to correctly choose the target item. Thus we were expecting children with SLI to choose fewer correct target items. However, we were particularly interested in the error patterns. Accordingly, there was a significant difference between groups on the accuracy of this task with the TD children scoring a mean of 15.4 (sd=4.8) whilst the children with SLI scored a mean of 11.6 (sd=4.6; ($F(1,37)=6.4$, $p=0.016$; cohen's $d=0.92$). When non-verbal raw score was controlled for, the difference became borderline significant ($F(1,36)=3.2$, $p=0.08$).

In total, 3/20 (15%) of children with SLI scored less than 8 out of 26 items (i.e. not significantly above chance) compared with 1/19 TD children (5%). This difference was not significant (Fishers exact p=0.61). There were no gender differences in the number of accurate guesses, either both groups together or separately.

Error patterns

The main aim of the comprehension task was to explore what strategies children in the two groups would use when both speech and gesture were not processed together. Focussing on the speech alone, or solely on the gestural cue would lead to a 50% error rate in this task. An error analysis was therefore conducted to see whether, in the case of not integrating speech and gesture correctly, the children with SLI would fall back on oral or gestural cues to guide their responses. Because of the different number of errors in each group, proportions of error types were calculated for each child (e.g., number of semantic errors /total number of errors x 100). Figure 1 shows the mean proportions across groups. As can be seen, whilst TD children showed a strong trend for semantically-based errors (they chose a spoken language alternative), and very few unrelated choices, those with SLI showed a clear tendency to choose a gesture-based foil when an error was made, and had a significantly higher proportion of unrelated guesses. Using a repeated measures ANOVA the interaction between these proportion error scores and group was significant ($F(1,36)= 16.5$, $p<0.001$) as was the main effect of error type ($F(1,36)=107.3$, $p<0.001$ (with unrelated being chosen significantly less often than the other two foils).

[Figure 1 about here]

Inter-relationships between experimental tasks and other skills

The two experimental tasks correlated significantly with each other when both groups were combined ($r(36)=0.39$, $p=0.02$) but this association was not significant in either group when considered separately (SLI: $r(18)=0.43$, $p=0.08$; TD: $r(18)=0.26$, $p=0.30$).

Further correlational analyses were undertaken to examine the relationships between the experimental tasks and other skills with both groups separately. These can be seen in Table 4.

Production task

When groups were examined separately regarding the production task, there were differing patterns for each group. For the TD children, fine motor skill ($r(17)=-0.55$, $p=0.02$) was significantly related to gesturing ability as was non-verbal cognition ($r(18)=0.47$, $p=0.048$). Neither expressive nor receptive language was associated with gesture production for TD children (both $r<0.3$; $p>0.05$). For the SLI group, on the other hand, correlations between language and gesture production skill were both moderate and significant (expressive: $r(18)=0.55$, $p=0.02$; receptive: $r(18)=0.52$, $p=0.03$) as was the association between non-verbal cognition and gesture production in the language impaired group ($r(18)=0.47$, $p=0.049$). Fine motor skill was not related to gesture production in this group.

Comprehension task

When groups were analysed separately on the comprehension task, expressive language was strongly associated for each group (TD r=0.69, p=0.001; SLI r=0.79 p<0.001). Receptive language was also significantly associated in the SLI group (r=0.67, p=0.001) and also showed a borderline significant relationship within the TD group (r=0.44, p=0.058). Non-verbal cognition was associated with comprehension task ability for those with SLI only (r=0.59, p=0.006) but fine motor skill was not correlated with comprehension task score for either group. See table 4 for all correlations.

[table 4 about here]

Discussion

This study aimed to explore the gestural abilities of a group with SLI compared to age peers in order to probe further how gestures and speech are used together by comparing performances across groups that differed in their verbal abilities. The findings provide evidence that gesture may act as a compensatory or scaffolding device in SLI, as is seen in younger typically developing children. This was evidenced in both between and within group analyses. Firstly, the children with SLI showed no difficulties producing symbolic gestures compared to peers. This was the case even though the gestures were not imitated. This supports other recent studies which show no differences between peers (Evans et al, 2001; Blake et al, 2008) in communicative gesture. They may seem contrary to the findings of Hill (1998) and Marton (2009), however recall that these two studies focused on imitation. As Marton points out, language related centres of the brain also involve imitation processes and it maybe that spontaneous gesture production and gesture imitation are relatively independent, whereas gesture imitation and language imitation (as in non-word repetition, for example) may be behaviourally more similar.

In addition, in order to aid the study of gesture we made steps towards the creation of new assessments of gesture that might be used to inform research and practice. Although further research is needed to fully achieve this goal, we nevertheless found that the tasks here showed satisfactory levels in terms of range of scores and reliability (inter-rater and internal consistency). This suggests that objective measures of non-verbal communication are a possibility, as well as the often used checklist-based assessments (such as the subscale of the MacArthur CDI, e.g., Bavin et al, 2008) or qualitative observational measures which are currently in use (e.g., Maniela-Arnold, Evans & Alibali, 2006).

The main findings of this study have important implications for the current debate about how gesture is involved in language production and processing, as well as for the understanding of the development of language and gesture in atypical populations. In this SLI group, we suggest that the conceptual representations of the items requested appeared to be in line with peers, and this information could be readily accessed and communicated non-verbally despite the children having significant impairments in spoken language. We would like to posit this as a preliminary result which will require further research to confirm. In particular we need to carry out more detailed qualitative analyses on the gestures, e.g., handshapes, location and viewpoint, to fully understand the nature of the gestures. The robustness of gesture in the face of SLI is particularly interesting in the light of a study by McGregor, Newman, Reilly and Capone (2002) showing that children with SLI have somewhat 'fuzzy' semantic knowledge compared to peers. The present research suggests SLI impacts on the semantics of the spoken element but not the gestural depiction of the same concept. It may be of course, that the current study task tapped into the type of gesture that children with SLI find the easiest. In Blake et al's study, for example, children with SLI produced more symbolic gesture and did so in contexts where a word was 'replaced'. Symbolic gesture use may not therefore be a spontaneous action for the typically developing group and may serve to 'even out' performance. On the other hand, the participants with SLI in the Blake et al study were also found to be unimpaired in other aspects of spontaneous gesture. In addition to using apparently age-appropriate gesture, children with SLI in the present study showed a preference for gestural cues when integration of speech and gesture broke down. Recall that no 'naming' was required for the comprehension task, and that to accurately identify the gesture children needed to integrate the verbal and visual inputs. The fact that adjusting for non-verbal IQ appeared to wash out differences in overall accuracy on this task, may indicate general processing limitation in the SLI group when attempting to integrate cross-modal information. However, the error analysis here allows us to start exploring the process behind complex comprehension. The increased gesture-based errors suggest that children were able to understand and use conceptual information in the perceived *gesture* even though this led them to make errors e.g. in the tiger example given earlier, they gleaned something about an object that is fierce and chose monster. This was in sharp contrast to their TD peers who were more likely to use spoken information in order to guess the meaning of the sentence e.g. they would choose hippo in the same sentence. Thus the children with SLI were able to exploit the embodied or action based etymology of the gestures both in production and comprehension.

Secondly, the inter-relationships of gestural ability and other skills in each group suggest that gesture is more closely inter-related with language for those with SLI. This supports Marton's (2009) finding that relationships between gestural movement and other skills were linked in a qualitatively different way when compared with typical peers. However whereas motor skill was the best predictor of imitation in Marton's study, this was not the case for either group in the present investigation. Rather the different pattern emerging from our analyses suggests that for those with impaired language, stronger correlations exist between language and gesture than for the TD children. Stefanini, Caselli and Volterra (2007) argue that in early language development TD children use gesture as lexical fillers or proto words. These gestures assist the development of the child's symbolic function, allowing the child to practice using symbols to refer to global actions or concrete objects, orientate their conversation partners before they have acquired spoken words for these situations and also begin to combine symbols in their first attempts at expressing basic semantic relations (Bates et al, 1979). Gesture often picks out symbolic properties of objects or some embodied representation of the action being described. This means the young child can use a symbol that has a direct relationship with the personal experience of carrying out that action (e.g. putting a fist at the side of the head to refer to using a telephone rather than articulating the string of phonemes 'I am telephoning'). Adults may also model these early gestures with their young infants (Capirci, Montanari & Volterra, 1998). Thus children might be able to exploit experience with objects use as a way to comprehend these gestures.

It is plausible that children with SLI, like their TD peers, are also able to use gesture in this way in early development. However, older children with SLI may continue to rely on more holistic and imagistic representations of information in gestures rather than replacing these fillers with words.

This may be possible if gesture in some way circumvents an impaired aspect of the language learning system. If part of the problem inherent in SLI is mapping a string of phonemes onto a concept and storing this word as a discrete vocabulary item, then accessing a gesture will be simpler. Older children have to learn the specific word order and morphological rules of their language needed to encode different semantic relations, however acting out an action might shortcut this mapping problem. Similarly if the child has a particular difficulty understanding the exact semantic relations in a verb phrase or decoding the morphology which specifies one meaning over another accessing an embodied action-based representation of a verb may be simpler. However, the problem with these gestures is they represent a restricted set of meanings, thus the children with SLI may be operating with a less semantically rich system when this is explored beyond a basic symbolic level. This limitation is partly reflected in the poorer performance of the SLI group when both language and gesture were required – the children with SLI made errors even when they focussed on the gesture part of the input because in this task (as we might argue in everyday conversation) they needed the verbal information to disambiguate the gesture.

The findings that children with SLI can exploit a gestural representation of objects and actions which are difficult in spoken language also suggests that the two sources of information may be somewhat independently retrieved from the lexico-semantic system. In unimpaired subjects' gestures may supply different semantic features in the absence of specific verbal labels for movement, in order to communicate that information (see Kita & Özyürek (2003) for a similar discussion). Thus gesture does not get consumed by the verbal part of the message but can act somewhat independently.

Further research

There is a clinical and theoretical need to understand the interplay between gesture and non-verbal development. In order to do this, and to compare across studies, we need to create valid and reliable measures of non-verbal communication. The gesture tasks used here are novel and show promising reliability, at least in terms of inter-rater concordance and internal consistency. However in order to check the usefulness of these standard gestures, future research should measure test-retest reliability and also improve validity by gathering data from adults, thus establishing a cultural-norm for responses on the tasks. In addition a future study based on spontaneous gesture production is required alongside more formal tasks, as a means of assessing concordant validity of test-based performance compared to gestural ability in naturalistic settings.

The range of scores in both SLI and TD groups also suggest that appropriate variance exists to develop an objective research paradigm for older children, without unwanted ceiling or floor effects. This might be particularly useful for children whose knowledge of concepts is difficult to test using standardized language tasks. However, further research needs to explore the item content of gesture, in particular how these relate to spoken language factors such as vocabulary/gesture age of acquisition, and the performance of different groups when gesture production items are more abstract. For example, no research exists examining whether there is a difference in comprehension of gestures depicting different parts of speech (e.g., noun-phrase, noun, adjective or verb). Furthermore, in terms of comprehending gesture and speech combinations, other paradigms, for example those which make use of narrative, need to be investigated. In the present study, no attempt was made to investigate and control for the *extent to which* the spoken content primed for the gesture at the end of the sentence. Gestural content could also be explored in a more dynamic and child centred way, using vocabulary items that are not easily accessed verbally, as in the Tip-of-the-tongue phenomenon. As noted above, the tasks developed here used only symbolic gestures and were in response to specific task demands – that is, like many standardized language tasks, children were asked to 'perform' a response in test conditions rather than in any naturalistic way. Further research is warranted into the assessment of gesture that accompanies speech and gesture in early pre-verbal development. Finally, this study is small and cross sectional. Larger scale longitudinal studies are needed so that more sophisticated techniques examining developmental trajectories and relations can be employed (see Thomas et al., 2009).

Clinical implications

The assessment of gesture would seem a useful additional tool for therapists and educators of children with communication impairments (Capone & McGregor, 2004). Indeed, in typically developing populations, teaching children to gesture appears to aid learning (Wagner Cook, Mitchell, & Goldin-Meadow, 2007). The present study suggests that objective assessment may be possible, although we acknowledge that the tasks here may need further development before clinical information can be derived from them: for example, the administration of a pre-test in order to see if children are familiar with the objects. However, the fact that language and gesture seem to be highly related in the SLI, but not the TD group appears to support the clinical approach of using increased gesture to bootstrap language development and language re-learning in cases of acquired language impairment therapy. In this study, our symbolic gestures were correlated with *vocabulary*, but it may also be that gestures can be used to add descriptive information, or to support syntactic understanding and learning. Indeed Makaton sign is often used to support children with limited language. There is always a concern that any success with taught symbolic gesture may be quite narrow, showing poor relationships to spoken language or spontaneous gesture. There is limited research into clinical use of gesture scaffolding in atypical populations but Ellis-Weismer & Hesketh (1993) showed increased learning of novel words when symbolic gestures accompanied speech in training and more recent studies have also suggested that gesture training may be clinically useful in other developmental populations (e.g., Autism: Ingersoll, Lewis & Kroman, 2007; Down Syndrome: Clibbens, Powell & Atkinson, 2002).

As our understanding of gesture processing, and typical and atypical development expands, populations with specific developmental disorders may serve to facilitate knowledge about the interaction of different linguistic and communicative skills. At the same time, further exploration into the potential strengths of children with communication impairments will enable us to advance clinical and educational support for these groups.

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Appendix 1 – Stimuli for comprehension task

Stimulus number	Sentence Stimulus (underlined portion is gestured, not said)	Gesture stimulus	Gesture foil	Linguistic foil	Oddball foil
1	He saw the lion with the <u>binoculars</u>	Put thumbs to index / second fingers and raise to eyes	Swimming goggles	Binoculars	Sponge
2	He goes to work by <u>car</u>	Steering wheel action	Someone skiing	A bicycle	A pillow
3	I played a game of <u>cards</u>	Make a movement as if opening a hand of cards	Reading a book	Someone playing tennis	A mouse
4	Do you fancy a game of <u>chess</u>	Pick up and put down a chess piece	A frog	Someone playing football	A piece of pie
5	These windows need a <u>wash</u>	Window cleaning action	Someone waving	Some curtains	A pillow
6	I'm not very comfortable. It's <u>cold</u>	Bunch up shoulders and rub opposite arms with hands	Two people hugging	Someone playing the violin	Someone playing football
7	She went to the mountains to <u>go skiing</u>	Make skiing movements with hands	People dancing	Someone rock climbing	Someone knitting
8	When he got to school he opened his <u>desk</u>	Make a lid-opening gesture	A mechanic fixing a car	A computer	A teacher
9	She's eaten all day and she's really <u>fat</u>	Puff out cheeks and use hands to show the size of one's stomach	Someone blowing up a balloon	Someone eating	Someone playing football.
10	At the party we saw some <u>fireworks</u>	Move hands in an inverted U-shape starting the middle of the U. As hands go down ripple fingers	A tree	Jelly	Some policeman

11	Swimming in the sea, I saw a <u>fish</u>	Flatten hand and point to camera with thumb up. Make a sinuous movement	A snake	A boat	A guitar
12	The joke was very <u>funny</u>	Laugh and hold hands to stomach	Someone with a stomach ache (grimacing and holding stomach)	Someone looking anxious	Someone lying on a beach
13	He's just popped out the <u>hairdressers</u>	Make a haircutting gesture using the index and middle fingers as scissors	A boy is scratching his head	A butcher is chopping meat	A dog is carrying a bone
14	He listened to the song on the <u>headphones</u>	Cup hands and put over ears	A child's bonnet	A stereo system	A weather vane
15	He watered the garden with the <u>hose</u>	Move hand backwards and forwards in a spraying action	A torch	A watering can	A cup of tea
16	I'm starving. Can I have a <u>hot dog?</u>	Make round shape with hand. Put it to mouth and do a biting action	Someone coughing	A sweet	A cat
17	He went up 10 floors using the <u>lift</u>	Put palm down. Move hand up slowly and smoothly	A mechanic fixing a car on a hydraulic lift.	A staircase	A basketball
18	My daughter's really good at playing the <u>piano</u>	Piano playing movement	Someone typing	Someone playing the violin	Someone playing football
19	She took him out in the <u>pram</u>	Grab handle and push it backwards and forwards	Someone rolling dough with a rolling pin	A car	A pan
20	He tasted the soup and added some <u>salt</u>	Clasp cellar, tip upsidown and shake	Someone sprinkling seeds	A jug of water	Some ants

21	He thought he saw something and was really <u>scared</u>	Open mouth and look scared. Open hands and hold to sides of face	Someone washing their face	Someone smiling	An old man in a hospital ward
22	She's learning how to <u>sing</u>	Open mouth in singing gesture. Hold hands in an operatic manner.	Someone yawning	Someone playing the piano	Someone eating a sandwich
23	My brother joined the army. Now he's a <u>soldier</u>	Do marching with arms held stiff	A robot	A postman	A hen
24	I went to the café and had some <u>tea</u>	Put thumb and index finger around a small handle and raise to mouth	A pipe	Some biscuits	Some people playing in an orchestra
25	In the zoo I saw a <u>tiger</u>	Snarl and make claws with hands	A monster	A hippo	A skeleton
26	After dinner he did the <u>washing up</u>	Put one hand flat, palm facing up (the plate). Make a scrubbing motion with the other (the cloth).	A shoe-shiner	Someone doing their homework	Some people running a race

Table 1: Participant characteristics

Group	Raven's raw score	EOWPVT	BPVS raw	Bead threading (secs)
SLI	13.7 (5.2)	39.3 (12.2)	39.6 (15.5)	326.6 (172.6)
TD	16.6 (5.2)	52.4 (11.7)	56.9 (11.5)	226.5 (145.1)
Comparison	$F(1,37)= 3.0$, $p=0.09$	$F(1,37)= 11.7$, $p=0.002$	$F(1,37)= 15.6$, $p<0.001$	$F(1,37)= 3.5$, $p=0.07$

Table 2: Gesture task characteristics

	Production task		Comprehension task	
Group	Skewness	Kurtosis	Skewness	Kurtosis
SLI	-0.64	0.06	0.42	-0.64
TD	-0.44	-0.64	-0.37	-0.41

Table 3: item by item and total score differences across groups

Target	TD Mean (SD)	SLI mean (SD)	F(1,34)	Sig.
Hamburger	3.4 (1.2)	2.5 (1.1)	5.17	0.03
Banana	2.4 (1.5)	2.1 (1.1)	0.38	0.54
Milkshake	2.9 (0.9)	2.9 (1.4)	0.02	0.89
Bowling	2.8 (1.2)	2.1 (1.5)	2.74	0.11
Boxing	3.1 (1.2)	2.8 (1.2)	0.47	0.50
Tennis	2.9 (0.8)	2.8 (1.0)	0.03	0.86
Karate	2.1 (1.6)	2.2 (1.5)	0.01	0.92
Javelin	3.0 (1.5)	2.6 (1.5)	0.75	0.39
Wind	0.9 (1.3)	1.6 (1.5)	2.16	0.15
Spider	1.9 (1.3)	1.9 (1.2)	0.02	0.89
Bird	3.1 (0.5)	3.0 (0.9)	0.21	0.65
Gorilla	2.3 (1.3)	2.1 (1.4)	0.14	0.71
Crab	2.3 (1.4)	2.0 (1.2)	0.41	0.53
Glasses	2.6 (1.0)	2.1 (1.5)	0.87	0.36
Scarf	2.7 (1.8)	2.1 (1.2)	1.21	0.28
Hat	2.8 (1.3)	1.7 (1.4)	5.44	0.03
Total production score	41.2 (11.1)	36.7 (13.1)	1.2	0.28

Table 4: Relationships between skills for SLI group and TD group respectively

TD group

	Gesture production	Gesture comprehension
Fine motor task	-0.55*	-0.39
Expressive language	0.22	0.69**
Receptive language	0.11	0.44
Non-verbal cognitive ability	0.47**	0.44

SLI group

	Gesture production	Gesture comprehension
Fine motor task	0.004	-0.21
Expressive language	0.55*	0.79**
Receptive language	0.52*	0.67**
Non-verbal cognitive ability	0.47*	0.59**

*p<0.05

**p<0.01

Figure 1: Proportionate errors by group