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Imitation of body postures and hand movements in children with specific language impairment

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Abstract

Within the domain-general theory of language impairment, this study examined body posture and hand movement imitation in children with specific language impairment (SLI) and in their age-matched peers. Participants included 40 children with SLI (5 years 3 months to 6 years 10 months of age) and 40 children with typical language development (5 years 3 months to 6 years 7 months of age). Five tests were used to examine imitation and its underlying cognitive and motor skills such as kinesthesia, working memory, and gross motor coordination. It was hypothesized that children with SLI show a weakness in imitation of body postures and that this deficit is not equally influenced by the underlying cognitive and motor skills. There was a group effect in each cognitive and motor task, but only gross motor coordination proved to be a strong predictor of imitation in children with SLI. In contrast, hand movement imitation was strongly predicted by performance in the Kinesthesia task in typically developing children. Thus, the findings show not only that children with SLI performed more poorly on the imitation tasks than their typically developing peers but also that the groups' performances showed qualitative differences. The results of the current study provide additional support to the view that the weaknesses in children with SLI are not limited to the verbal domain.

Keywords

Imitation of body postures; Imitation of hand movements; Kinesthesia; Working memory; Motor control; Specific language impairment

Introduction

Imitation plays a central role in the development of motor control, speech/language/communication, and social life (Tomasello, Kruger, & Ratner, 1993). Imitation is one of the most common ways for children to acquire motor or speech/language skills. Children use imitation to learn new motor skills and communicative actions and to facilitate comprehension of other individuals' behavior (Goldenberg & Karnath, 2006). As children learn to speak, they acquire speech/language by hearing the spoken words and speech sounds and not by receiving instructions on how to manipulate their articulators (Jordan & Rumelhart, 2002). Although children start to imitate very early in their lives, imitation is a complex task. The development of it is highly influenced by children's perceptual and gross motor skills and by higher cognitive functions such as working memory.

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The Broca's area in the brain has an imitation mechanism through which the interpretation of hand movements is closely linked to language performance (Rizzolatti & Arbib, 1998). The motor area for speech appears to be responsible for directly matching the linguistic material and motor movements (Iacoboni et al., 1999). The Broca's area contains a matching system that facilitates language acquisition through imitation. This area has special importance in primates with respect to gestures and in humans with respect to language acquisition and processing (Cooper, 2006). Gesture, speech, and language are interrelated and show an overlap in neural control (Capone & McGregor, 2004).

The target population of this study, children with specific language impairment (SLI), experience difficulties in both language comprehension and production. These children show a later onset and slower progress in language development in the absence of hearing impairment or intellectual disorder. Although by definition the primary deficit in children with SLI is in language, an increasing number of researchers have suggested that these children's difficulties are not limited to their language skills (e.g., Archibald & Gathercole, 2006; Botting, 2005; Hill, 2001; Marton & Schwartz, 2003). Children with SLI show poor performance in working memory (e.g., Ellis Weismer, Evans, & Hesketh, 1999; Marton & Schwartz, 2003; Montgomery, 2000), in attention control (Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow, 2001), in procedural memory (Ullman & Pierpont, 2005), in nonverbal cognitive development (Botting, 2005), in visuospatial processing (Hick, Botting, & Conti-Ramsden, 2005; Marton, 2008), and in gross motor control (Bishop, 2002; Hill, 2001). Many of these skills have been reported to play a relevant role in imitation. Imitation is not a simple matching mechanism; it includes various motor, perceptual, and cognitive elements such as visuomotor perception, visual attention, short-term memory (Decety, 2006). Although imitation plays a major role in language development, the imitation skills of children with SLI is an uncharted area. Given the accentuated role of the Broca's area in imitation and the hypothesis that this area and the frontal/basal ganglia circuits are impaired in children with SLI (Ullman & Pierpont, 2005), we may expect a deficit in body posture and movement imitation in this population. Thus, the overall aim of this study was to examine different forms of body posture and hand movement imitation and the underlying motor and cognitive skills in children with SLI.

Language is a complex system that is interrelated with a number of nonverbal factors. Examples of these functions include imitation, gestures, gross motor control, and social engagement. We know that these factors affect language acquisition, but it is not clear which of these functions predict language impairment in specific disorders (Tager-Flusberg, 2005). Only a few studies have examined motor control in children with SLI, but their results indicate a relatively high prevalence of impairments in gross motor skills and gestures in this population. Motor performance is an indicator of underlying neuro-developmental immaturity (Bishop, 2002). Based on the fact that the perceptual–motor translation is a defining property of imitation (Heyes, 2001), one would expect that children with poor gross motor skills show difficulty in imitation tasks.

In a review article, Hill (2001) concluded that an increase in task complexity and/or in the number of processes required to complete a motor task results in an increase in group differences between children with SLI and their typically developing peers. Thus, children with SLI not only perform more poorly than their peers in different motor tests but also show a more dramatic decline in performance with an increase in task complexity. This is in line with our previous findings on verbal cognitive tasks, where one of the major challenges for children with SLI was to perform simultaneous processing (Marton & Schwartz, 2003; Marton, Schwartz, Farkas, & Katsnelson, 2006).

Children with SLI performed more poorly than controls in finger tapping and peg moving tasks in a behavioral genetic study (Bishop, 2002) where the author found significant shared genetic variance for weaknesses in peg moving and in nonword repetition, a test of phonological working memory. Based on these outcomes, it was concluded that the genes that are responsible for communicative impairments also affect motor development. There is further evidence for the link between speech/language impairment and weak motor development in studies on representational gesture production (Capone & McGregor, 2004). Children with SLI performed similar to younger motor-matched control children in gesture tasks of common actions (e.g., teeth brushing). Although the children with SLI demonstrated accurate gesture representations, their actions included spatial and/or orientation errors (Hill, Bishop, & Nimmo-Smith, 1998).

An area related to motor control is kinesthesia. It is the skill of perceiving one's own limb position and limb movements. Previous research has shown that kinesthesia plays a special role behind the weaknesses in imitation in children with autism (Rogers, Hepburn, Stackhouse, & Wehner, 2003). There are no studies on kinesthesia in children with SLI, but it is a skill that needs to be examined in these children because it is related to motor movements and has an impact on children's imitation performance.

In addition to gross motor control, imitation is also linked to certain cognitive mechanisms, executive functions, and working memory (Williams, Whiten, Suddendorf, & Perrett, 2001). Imitation of complex body postures requires motor planning, inhibition of irrelevant gestures, and continuous monitoring of body movements. There is empirical support for the view that imitation is determined by the sensorimotor translation that occurs during the process of observing movements and carrying out those movements (Heyes, 2001). Imitation involves the coordination among the sensory input, action coding, and visual transformation between the self and the other (Williams et al., 2001). Thus, a limitation in executive functions and working memory may have a negative impact on imitation of the other person's body postures. There is evidence in the literature that children with SLI show a weakness in working memory and in executive functions such as inhibition control, updating, and attention switching (Im-Bolter, Johnson, & Pascual-Leone, 2006; Marton, 2008).

Purpose of the current study

The overall theoretical frame for this article is the domain-general theory of language impairment. This theory suggests that if certain underlying mechanisms such as inhibition and motor control are impaired, they will affect various verbal and nonverbal functions (Karmiloff-Smith, 1998). Within this theoretical frame, the aim of the current study was to examine body posture imitation and the underlying kinesthetic, gross motor, and working memory skills in children with SLI. The following hypotheses were tested in this study:

1. Based on previous findings that point to the complexity of imitation (the number of motor and cognitive elements that are involved), it was proposed that children with SLI will perform more poorly than their peers on tasks that target body posture and hand movement imitation.
2. It was proposed that children who show a deficit in body movement imitation will show problems in kinesthesia, gross motor control, and working memory.
3. It was proposed that although motor coordination, kinesthesia, and working memory all influence children's imitation skills, depending on the participants' strengths and weaknesses and on the nature of the imitation tasks, the above functions will not predict children's imitation performance equally well.

Method

Participants

This study is part of a larger investigation that examines the relations among working memory, executive functions and social cognition in children with SLI. Two groups of Hungarian children (*N* = 80) participated in this study: 40 children with SLI (5 years 3 months to 6 years 10 months of age) and 40 chronologically age-matched peers (5 years 3 months to 6 years 7 months of age). The children in the first group had been diagnosed by a speech/language pathologist as specific language impaired. All children with SLI participated in both individual and group speech/language therapy on a weekly basis. There is no comprehensive standardized language test in Hungarian, but all children performed approximately 1.5 to 2.0 years below the age average on Hungarian language tasks such as sentence comprehension and word recall (see participant profile in Table 1).

The second group was composed of chronologically age-matched (within 3 months) children with typical language development. None of these children had a history of speech/language delay or disorder. Based on parental reports, all children in this group attended public school and performed at age-appropriate levels in both learning and behavior.

None of the participants had a history of any frank neurological impairment or psychological disturbances. All children were monolingual Hungarian speakers. All of them performed within the normal range on the Snijders–Oomen Nonverbal Intelligence Test–Revised (Snijders, Tellegen, & Laros, 1989). To ensure that all participants had average visuospatial short-term memory, the groups were matched along this dimension.

Stimuli

Imitation of postures task—This task (Ayres, 1980) tested children's ability to perceive and imitate different body positions. The task includes 12 body positions that are presented by the experimenter one at a time. It requires close observation of the posture, motor planning, and movement execution. To perform well on this task, children need good sensation of their own body position. Children receive 2 points for every correct body posture imitation if it is performed within 3 s, and they receive 1 point if it is performed within 10 s. Children are instructed to perform the imitation as quickly as possible. No points are given for imitations that occur after 10 s or for postures that deviate from the model. (See Appendix A for examples of target postures.)

Bilateral motor coordination task—This task (Ayres, 1980) examines hand movement coordination. Children need to imitate various patterns of tapping and clapping. Some of the items require symmetrical hand movements, and other items need to be performed with asymmetrical hand movements. This task is based on the coordination of the two sides of the body. To perform well on the task, children need good motor planning and execution. The task consists of eight items.

Kinesthesia task—This task (Ayres, 1980) targets children's awareness of body position and movements. Children are prevented from seeing the sheet on which the examiner moves their hand (finger) from one predetermined point to another. Children need to repeat the movement based on their sensation of the movement without seeing their hands. The task consists of 10 items, alternating the right and left hands. The distance between the predetermined point and the point where children's finger reaches the sheet is measured. Raw scores are calculated based on the distance measured in millimeters.

Manual form perception task—This task (Ayres, 1980) was used in the current study because it is highly demanding on working memory. Although the selection process of this study included working memory tasks (see Table 1), those tasks were common verbal working memory measures. We used them to ensure that the children with SLI in the current study show the typical profile known from the literature. The Manual Form Perception task tests working memory in a different way. The first part of the task is similar to any stereognosis tests, where participants need to identify, with the exclusion of visual input, a geometric form (e.g., star, circle, octagon, triangle) placed in their hands (alternating left and right). The task requires that participants first process the tactile input and then match it to the visual counterpart. To find the matching visual counterpart, participants need to form a visual image of the tactile input. Children are shown a table with many similar, and thus distracting, figures. They are asked to point to the appropriate geometric form. This task is highly demanding on working memory because participants need to remember the tactile input, transform it into a visual image, and find the appropriate form in the context of many similar figures that interfere with the stimulus item. Participants received 2 × 10 items. Performance was scored as either correct or incorrect.

Motor coordination test (Körperkoordinationstest für Kinder)—This test (Kiphard & Schilling, 1974) measures gross motor coordination. It consists of four items: balancing backward, hopping, jumping from side to side, and transferring boxes. Raw scores from each item are transformed into an overall motor quotient (*MQ*: mean = 100, *SD* = 15). In the first item, participants are required to walk backward along a balance bar. The goal is to measure steadiness of balance while walking backward on the bar. The number of successful steps is recorded. In the second item, children are asked to jump on one foot over a pile of foam squares. As children advance in the task, more foam squares are placed on top of each other. Thus, children are asked to jump higher. The goal is to examine coordination and strength of the lower limbs. The experimenter records the number of foam squares at the last successful jump of children. In the third item, participants are asked to jump from side to side over a small beam by keeping their feet together. Children are instructed to jump as many times as they can within a period of 15 s. The goal is to measure speed of jumping. The score is based on the total number of correct jumps. The fourth item tests a sequence of gross motor movements. Two small wooden boxes (footstools) are used to perform the task. Children stand on one of the boxes and hold the other one in their hands. Participants are then asked to place the second box alongside the first one and to step over onto this second box. Then they need to lift up the first box and place it down next to the other one. This sequence of movements is continued, and the number of correct movements is recorded. The goal is to examine children's motor planning and organization.

Procedures

Participants were tested in two sessions in the current study. Testing was performed in participants' schools. Each session lasted approximately 45 to 60 min. To decrease experimenter bias, different research assistants participated in testing and data analysis. All experimental tasks were administered according to the test manuals (Ayres, 1980; Kiphard & Schilling, 1974). To minimize the learning/sequencing effect, the experimental tasks were presented in a randomized order. The same research assistant read the instructions from the protocol for each participant. Children's performances were recorded on protocol sheets. Scoring was performed in accordance with the manuals. Children's raw scores were converted into *Z* scores for the Imitation of Postures, Bilateral Motor Coordination, Manual Form Perception, and Kinesthesia tasks, and motor quotients were calculated for the Motor Coordination test.

An error analysis was performed for the Imitation of Postures task. The following categories were developed for this analysis: perseveration, simple omission, simple substitution, complex omission, and “other.” Perseveration errors included those body positions that had been the target in the previous tasks. Simple omissions referred to body posture imitations, where the global posture was correct but a smaller detail was omitted (e.g., the child crossed the body with one hand but did not place the other hand on the hip). Simple substitution errors were those where the overall posture was correct but the child substituted a small detail (e.g., in body crossing, the child placed his or her hands not on the hip but rather on the waist). An error was considered as a complex omission when the child produced a detail of the posture but missed the overall look of it (e.g., the child did not cross the bodyline with one hand when doing so was required). Other errors were random posture productions that did not fit into any of the above categories.

Results

The first hypothesis of this study was that children with SLI show a weakness in imitation of body postures and hand movements compared with their typically developing peers (see Table 2). Two tasks were used to confirm this hypothesis: Imitation of Postures and Bilateral Motor Coordination. These two tasks showed strong correlation, $r = .59$, $p < .001$. There was a main effect for group in the Imitation of Postures task, $F(1, 78) = 30.57$, $p < .001$, $d = 1.21$. Children with SLI performed more poorly than their age-matched peers, and there was a large effect size. The results of the Bilateral Motor Coordination task also showed a group effect and a large effect size, $F(1, 78) = 49.32$, $p < .001$, $d = 1.62$. The group differences for both of these tasks remained after using analyses of covariance (ANCOVAs) to control for nonverbal IQ: Imitation of Postures, $F(1, 77) = 9.09$, $p < .01$; Bilateral Motor Coordination, $F(1, 77) = 14.34$, $p < .01$. Successful imitation of body postures and hand movements requires both the analysis of details and the perception of the global posture. A number of children with SLI either focused on specific details without imitating the overall posture or imitated the global posture without noticing important details (e.g., whether the arms are crossed in front of the body or behind it). Contrary to these errors, typically developing children showed good perception of the overall posture, with their errors reflecting smaller deviations from the model (see Fig. 1).

The second hypothesis of this study was that children with SLI perform more poorly than typically developing children on those tasks that measure the underlying skills of imitation: kinesthesia, working memory, and motor control. In the Kinesthesia task, the results showed a main effect for group, $F(1, 78) = 9.14$, $p < .01$, $d = 0.70$, and this group difference remained after using an ANCOVA to control for nonverbal IQ, $F(1, 77) = 4.71$, $p < .05$. Children with SLI indicated more difficulty in kinesthesia than did their age-matched peers. These children showed a weakness in sensing their own body parts in space and in controlling their hand movements.

Children's performance on the Manual Form Perception task, which is highly demanding on working memory, also showed a group difference, $F(1, 78) = 9.31$, $p < .01$, $d = 0.70$, although this difference did not remain significant after controlling for nonverbal IQ, $F(1, 77) = 2.80$, $p > .05$. This result was not unexpected. One reason for this loss is that nonverbal IQ is a global score that is likely measuring working memory and executive functions.

A one-way analysis of variance (ANOVA) was used to confirm the proposition that children with SLI show immaturity in their overall motor performance compared with typically developing controls. The two groups differed significantly from each other on the Motor Coordination test, and there was a large effect size, $F(1, 78) = 147.93$, $p < .001$, $d = 2.72$. Children with SLI performed more poorly than the control group in gross motor performance, with their overall scores falling nearly 2 standard deviations below the average (see Table 2). There were noticeable individual variations in motor control in the group of children with SLI.

The scores for the four items were not analyzed individually because the focus of this article is not on a detailed description of various gross motor skills in children with SLI.

The third hypothesis of this study was that some underlying motor and cognitive skills are better predictors of body posture and hand movement imitation than are others. To test this hypothesis, we performed a multiple regression analysis within the groups, where the scores from the Motor Coordination test, Kinesthesia task, and Manual Form Perception task were used as the independent variables and the performances on the Imitation of Postures task and Bilateral Motor Coordination task were used as the dependent variables. The results showed different patterns for the two groups (see Tables 3 and 4).

In children with SLI, gross motor performance appeared to be a significant predictor of imitation skills in both the Imitation of Postures task and Bilateral Motor Coordination task. The *t* values indicated that neither kinesthesia nor working memory had a significant contribution to performance on the imitation tasks. The results of the multiple regression analysis for typically developing children showed a different pattern.

In determining the relative importance of the predictor variables, the *t* values indicated that neither working memory nor gross motor control had a significant contribution to children's performance on the imitation tasks but that kinesthesia predicted children's hand movement imitation. Thus, not only did children with SLI perform more poorly on the imitation tasks than their typically developing peers, but also the groups' performances showed qualitative differences. Gross motor performance appeared to be a strong predictor of body posture and hand movement imitation in children with SLI but not in children with typical language development. Performance on the Kinesthesia task did not predict imitation performance in children with SLI, but it appeared to be a strong predictor of hand movement imitation in typically developing children.

A qualitative difference in performance pattern between the groups was further evidenced by the data of the error analysis of the Imitation of Postures task. Children with SLI produced many perseverative errors and complex omissions, whereas most of the errors of typically developing children were simple omissions and simple substitutions.

Discussion

This study examined body posture and hand movement imitation and their relations to kinesthesia, working memory, and gross motor skills in children with SLI and in their age-matched peers. The Imitation of Postures task and Bilateral Motor Coordination task were used to test children's body posture and hand movement imitation abilities. We examined children's awareness of body position and movements with the Kinesthesia task. The Motor Coordination test (Körperkoordinationstest für Kinder) was used to study overall motor control, and the Manual Form Perception task was administered to examine the impact of working memory on imitation. To imitate complex body postures, individuals need to focus on the model and concurrently monitor their own movements and body positions. The successful imitation of a body posture requires that children compare the actual position with the original posture and that they make adjustments if needed. This is a complex task that involves the perception of one's own body scheme, working memory, monitoring performance, and motor coordination. This is why we examined the relationship among body posture and hand movement imitation and kinesthesia, working memory, and gross motor performance in the current study.

Children with SLI performed more poorly than their peers in body posture imitation, and their performances indicated more complex errors than those observed in typically developing children. The majority of the errors presented by typically developing children were simple; they either missed or substituted one aspect of a complex posture (e.g., when clasping the hands, children did not always notice whether the right or left finger was in front; when crossing the midline of the body, children may have overlooked whether the hands rested on the hip or the waist). In contrast to these problems, children with SLI produced more complex errors. They often missed the overall look of the imitated body posture (e.g., if the posture involved the crossing of the midline of the body, they produced a posture without crossing the midline; they imitated the modeled position of the arms but missed the positions of the legs; they did not notice specific arm positions that were produced behind the body). Many of the errors of children with SLI included perseverative movements. When switching from one posture to the other, children with SLI often produced body positions that had been the target in the previous tasks. This type of error occurred only rarely in typically developing children (see Fig. 1). Perseverative errors may result from a deficit in inhibition control, from poor attention switching, or from working memory limitations. Further research is needed to understand the reason for the high number of perseverative errors in children with SLI. This finding, however, is in agreement with our previous data on verbal working memory tasks, where most of the errors produced by children with SLI were perseverations (Marton, Kelmenson, & Pinkhasova, 2007).

The findings on the Bilateral Motor Coordination task were similar to the results on the Imitation of Postures task. In the Bilateral Motor Coordination task, children were required to imitate hand clapping and sequences of hand movements. A common error for typically developing children was that they forgot a part of the sequence. In contrast, children with SLI produced many perseverative chains of movements. It was difficult for them to switch from one pattern to another. Further research is needed to examine whether this problem is related to task switching, to inhibition, or to a combination of these executive functions. Poor imitation of body postures and hand movements in children with SLI might also reflect a weakness in perspective taking combined with difficulty in attention switching. Successful imitation requires that the person actively attends to the partner and shows specific responsiveness to the partner's behavior (Gergely & Csibra, 2005). The difficulties that children with SLI experienced in matching the experimenter's behavior seemed to be related to problems in dividing their attention between self-focus and perception of others. Self-focused attention inhibits behavioral matching (Dijksterhuis & Bargh, 2001). Typically, an individual switches his or her attention from the self to the other person numerous times during the imitation process.

The second aim of this study was to examine whether poor imitation of body postures is influenced by a weakness in kinesthesia, working memory, and motor control. It has been suggested that imitation skills are closely associated with all of these functions. Imitation is influenced by kinesthesia, that is, the awareness of the position and movement of particular body parts (Rogers et al., 2003). Children with SLI performed more poorly on the Kinesthesia task than did children in the control group. One common error among children with SLI in this task was the production of impulsive responses. These children could hardly wait for the experimenter to move the hand from a predetermined point to another and back to the original place. With the exclusion of vision, children with SLI showed difficulty in focusing on the sensation of their own body position and movement. These children were less accurate than their peers in replicating rehearsed movements. Typically developing children focused more intensely on their body movements guided by the experimenter. The more closely children observe the modeled movement, the closer they get to the target points.

The multiple regression data of typically developing children support the notion that kinesthesia is closely linked to imitation performance. Performance on the Kinesthesia task was a strong predictor of hand movement imitation in typically developing children. This finding was not unexpected because it is crucial to have good perception of the hands' and arms' position and movements to imitate complex hand movements. Our results of typically developing children are in line with the findings of Bar-Haim and Bart (2006). Those authors reported a strong correlation between kinesthesia and imitation in 5-and 6-year-olds. It is important to note that a different pattern emerged for the children with SLI. Not only did these children perform more poorly than their peers on the Kinesthesia task, but also their performance did not predict their body posture and hand movement imitation scores. There may be various explanations for this finding, but these results show that children with SLI do not follow the typical processes in imitating hand movements. These children could have performed more poorly than their peers in perceiving their own limbs' position and movements yet still showed a relationship between kinesthesia and imitation. Their poor imitation of hand movements could have been predicted by their weakness in kinesthesia. This was not the case in the current study.

Imitation is a complex function that is interrelated with a number of cognitive skills, and working memory is one of them. In complex imitation tasks, children need to remember abstract goals that they convert into the corresponding sensory realizations (Jordan & Rumelhart, 2002). Participants' imitation performance is often affected by a limitation in cognitive resources. An increase in the number of goals resulted in an increase in the number of errors (Rumiati & Bekkering, 2003). The body posture imitation task in the current study included novel and meaningless postures that had no correspondence with representations in participants' long-term memory. Thus, children could not rely on their long-term knowledge to supplement their working memory. The current results on working memory are in agreement with common findings that suggest a weakness in children with SLI (e.g., Hick et al., 2005; Im-Bolter et al., 2006; Marton, 2008). The results provide further support to the notion that children with SLI have a domain-general deficit in working memory. These children's working memory problems are not limited to the verbal domain. Although children with SLI performed poorly on the working memory task, this result did not predict their imitation performance. The test that appeared to be the strongest predictor of both body posture and hand movement imitation in children with SLI was the Motor Coordination test.

Imitation of meaningless body postures requires double mapping, that is, mapping from visual perception to motor execution of a given action and mapping from another person's body to the child's own body (Goldenberg, 2001). This complex process requires good motor control and high familiarity with one's own body schema. Children with SLI performed more poorly on all gross motor tasks than did their typically developing peers. A number of children in the SLI group performed the test with a cramped position and produced awkward sequences of movements. This was particularly evident on the last item, where children needed to coordinate their movements in a structured sequence. These children showed a weakness in controlling their body movements in an organized way. The current findings are in agreement with previous data that revealed substantial comorbidity between SLI and poor motor control (Hill, 2001; Webster et al., 2006). In the current study, the focus was on examining children's body posture imitation. Therefore, the data from the gross motor coordination test were not analyzed in detail. Only the overall scores were used to explore the relationship between SLI children's motor coordination skills and imitation performance. It is important for future research to examine the observed gross motor problems in more detail.

Taken together, the findings of this study reveal significant associations between body posture imitation and motor skills. Children with SLI showed significantly poorer performance than did their age-matched peers in both body posture imitation and motor control. The group differences across tasks support the views of a domain-general theory of language impairment. The error analysis data further confirm this hypothesis. Children with SLI showed performance patterns different from those of their peers, and many of these errors were similar to those observed in verbal tasks. This finding indicates that these problems are not domain specific. The most common error among children with SLI was perseveration, whereas typically developing children produced more simple omissions or substitutions. The findings on poor body posture and hand movement imitation in children with SLI suggest that a weakness in imitation skills may serve as a risk factor for language impairment during early childhood. The neuroconstructivist view suggests that we focus on at-risk populations before the onset of language. The findings within this account have shown that children with language impairment often demonstrate weaknesses in various underlying areas such as motor control (Karmiloff-Smith, 1998). Motor control proved to be a strong predictor of imitation in children with SLI in the current study. Thus, examination of motor control and imitation in infants who are at risk for language impairment may help us to identify the problems prior to the onset of the first words.

The focus of this study was on conscious imitation of meaningless body positions. Social situations often involve the unconscious imitation of body postures, facial expressions, and gestures (LaFrance, 1982). It is an important task for future research to compare the various types of body posture imitation in children with SLI. Furthermore, we do not know whether poor imitation in children with SLI is restricted to the outward signs in behavior or is related to a difference in brain activity. Neurophysiological studies could reveal whether children with SLI show activity in the premotor cortex similar to that of typically developing children when they are watching someone's body movements. Poor imitation skills negatively affect both learning and social relationships. Imitation skills have a high impact on children's reasoning and observational learning (Bates, 2003) and on their social life, particularly in forming successful peer relationships (Jerome, Fujiki, Brinton, & James, 2002). Thus, in addition to theoretical advancement, the findings on a deficit in body posture imitation in children with SLI have strong clinical implications.

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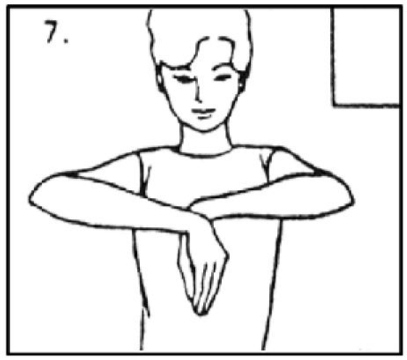
Appendix

Appendix A

Examples from the Imitation of Postures task (Ayres, 1980).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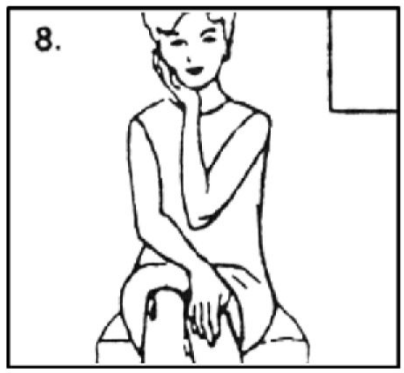
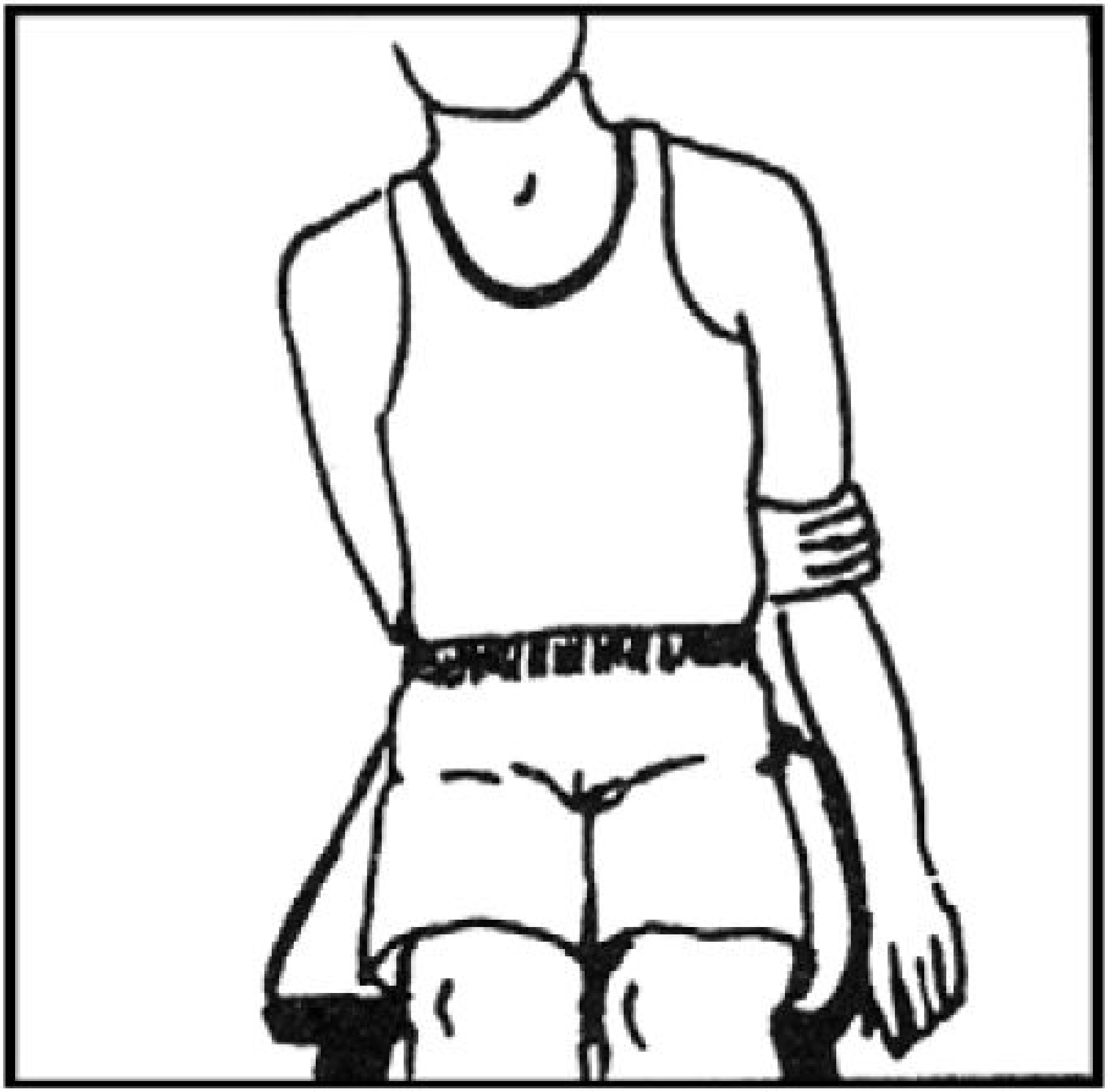

8.



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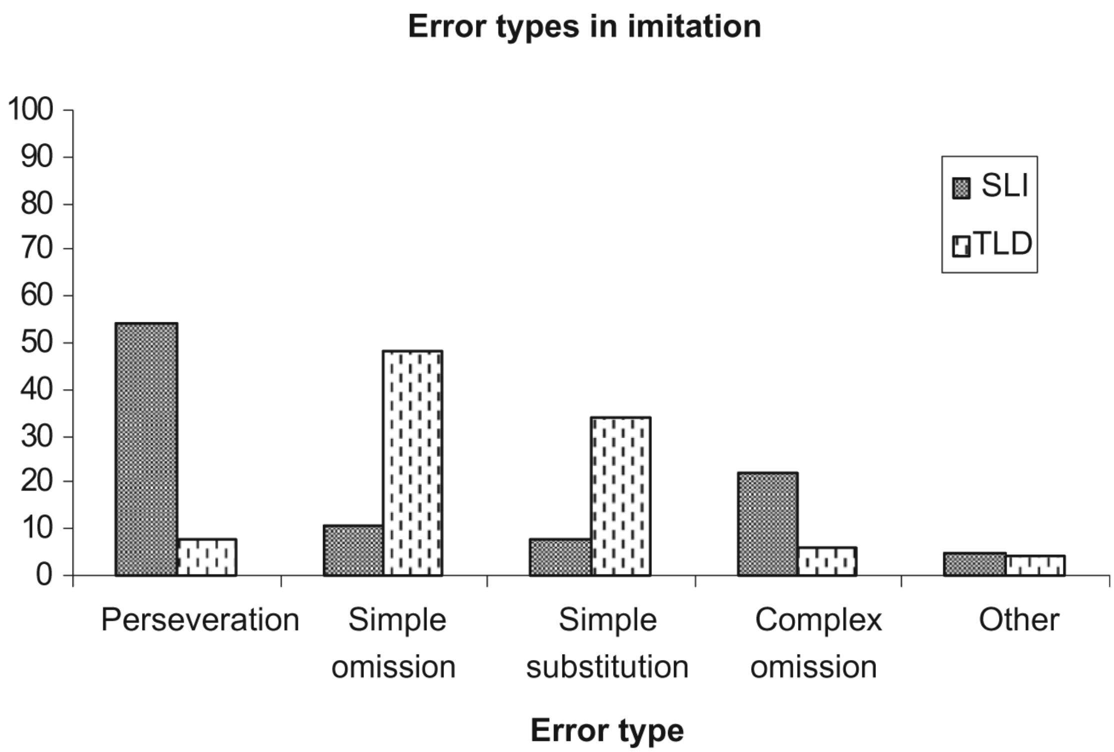

Fig. 1.
Distribution of errors within groups (percentage of all errors per group). SLI, specific language impairment; TLD, typical language development.

Table 1

Participant profile

	SLI	Control
Gender: Female (*N*) / Male (*N*)	12/28	12/28
Age: Mean (SD)	6.33 (0.49)	6.36 (0.32)
Nonverbal IQ: Mean (SD)	98.02 (9.6)	110.8 (7.3)
Visuo-spatial short-term memory: Mean standard score (SD)	24.93 (2.18)	26.5 (2.21)
Sentence comprehension (including complex sentences: Mean % correct (SD)	66.63 (24.37)	87.82 (18.15)
Word recall: Mean % correct (SD)	61 (8.43)	93 (9.81)
Verbal working memory: Mean % correct in listening span (SD)	30.48 (17.23)	87.14 (10.16)

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Table 2

Means and standard deviations of performance across tasks

	SLI		Control	
	***Z*-scores**	**Motor quotient (MQ)**	***Z*-scores**	**Motor quotient (MQ)**
Postural imitation mean (SD)	−0.31 (1.2)	–	0.97 (0.89)	–
Bilateral motor coordination mean (SD)	0.1 (1.03)	–	1.43 (0.53)	–
Kinesthesia mean (SD)	−0.88 (1.56)	–	0.07 (1.13)	–
Manual form perception mean (SD)	−1.25 (1.18)	–	−0.43 (1.19)	–
Motor coordination in children	–	72.88 (14.49)	–	104.7 (8)

Table 3

Multiple regression analysis data for children with SLI

Independent variables	**Dependent variable**	***R* Square**	***F***	***p***
Kinesthesia, Motor coordination, Manual form perception (working memory)	Posture imitation	0.34	6.26	<0.01
Kinesthesia, Motor coordination, Manual form perception (working memory)	Bilateral motor coordination	0.23	4.67	<0.05
		Beta	*t*	*p*
Kinesthesia	Posture imitation	−0.14	−0.95	>0.05
Motor coordination		0.04	3.25	<0.01
Manual form perception (working memory)		0.22	1.46	>0.05
Kinesthesia	Bilateral motor coordination	−0.04	−0.35	>0.05
Motor coordination		0.45	2.4	<0.05
Manual form perception (working memory)		0.17	1.2	>0.05

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Table 4

Multiple regression analysis data for children with typical language development

Independent variables	**Dependent variable**	***R* square**	***F***	***p***
Kinesthesia, motor coordination, manual form perception (working memory)	Posture imitation	0.18	2.61	>0.05
Kinesthesia, motor coordination manual form perception (working memory)	Bilateral motor coordination	0.29	4.79	>0.05
		Beta	*t*	*p*
Kinesthesia	Posture imitation	0.2	1.67	>0.05
Motor coordination		0.03	1.78	>0.05
Manual form perception (working memory)		−0.03	−0.27	>0.05
Kinesthesia	Bilateral motor coordination	0.2	3.08	<0.01
Motor coordination		0.01	0.58	>0.05
Manual form perception (working memory)		0.09	1.37	>0.05