Understanding Conservation Delays in Children With Specific Language Impairment: Task Representations Revealed in Speech and Gesture

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Purpose: The authors investigated mental representations of Piagetian conservation tasks in children with specific language impairment (SLI) and typically developing peers. Children with SLI have normal nonverbal intelligence; however, they exhibit difficulties in Piagetian conservation tasks. The authors tested the hypothesis that conservation difficulties may be due to the degree to which children with SLI rely on external perceptual features of the task as opposed to internal cognitive knowledge about transformation.
Method: Twenty-nine children participated, 12 children with SLI (ages 7;0–10;5) and 17 typically developing peers (ages 5;4–10;9) who were matched either on chronological age (CA) task or on judgments on the conservation task (conservation matched [CM]). Children solved conservation tasks and then explained their reasoning. Explanations produced in speech and gesture were analyzed.
Results: In speech, children in the SLI group expressed proportionately fewer internal explanations than the CA group, but a similar proportion of internal explanations as compared with the younger CM group. In gesture, children with SLI did not differ from either CA or CM children.
Conclusions: Children with SLI have weak internal representations of the concept of conservation, similar to those of younger children. Conservation representations appear to be closely related to language skills and verbal working memory.

KEY WORDS: specific language impairment (SLI), nonverbal cognition, conservation, gesture, task representations

This study investigated mental representation of Piagetian conservation tasks in children with specific language impairment (SLI) and their typically developing peers. Children with SLI exhibit delayed language development in the absence of frank neurological, hearing, emotional, or intellectual impairments. These children typically have a delayed onset and slower progression of developing language skills, characterized by lexical, syntactical, and especially morphological difficulties (for a detailed review, see Leonard, 1998). Although by definition, children with SLI have normal nonverbal intelligence, there is a substantial and growing body of research suggesting deficits on a range of nonverbal tasks as well (for a detailed review, see Bishop, 1992; Leonard, 1998). Some of these difficulties include problems with manipulating mental images in mental rotation tasks (Johnston & Ellis Weismer, 1983), deficits in hypothesis testing (Nelson, Kamhi, & Apel, 1987; Ellis Weismer, 1991), poor haptic recognition (Kamhi, Catts, Koenig, & Lewis, 1984; Montgomery, 1993), and delayed acquisition of Piagetian conservation (e.g., Inhelder, 1963; Evans, Alibali, & McNeil, 2001; Kamhi, 1981; Siegel, Lees, Allan, & Bolton, 1981).

The basic logic of conservation tasks is that a quantity stays the same across transformations unless more is added or some is taken away. Conservation tasks can be administered using liquid, countable objects, sticks of certain length, or shapeable mass. Each of these tasks begins with establishing the initial equality of two quantities. For example, the investigator pours the same amount of water into two identical glasses. After the child agrees that the two amounts are the same, the investigator transforms one of the items so that it appears different, although the amount is unchanged. For example, the investigator pours the water in one of the glasses into a shorter, wider one. Next, the investigator asks the child to judge whether there is more in the unchanged item, more in the changed item, or the same amount in both. A judgment is regarded as conserving if the child indicates that the amounts are the same, and nonconserving if the child indicates that the amounts are different. Typically developing children between the ages of 6 and 7 conserve across the full range of tasks, including liquid, number, length, and mass (Siegler, 1981).

Studies of children with SLI document delays in conservation performance. For example, Siegel et al. (1981) and Kamhi (1981) reported that children with SLI between the ages of 4 and 6 performed less well than typically developing, age-matched children, but better than typically developing, language-matched children. Studies of older children with SLI, however, indicate that ultimately these children are able to perform successfully on conservation tasks, albeit 3–4 years later than their typically developing peers. For example, Inhelder (1963) and Johnston and Ramstad (1983) both observed older children with SLI (9–11-year-olds) to exhibit fully conserving performance. Taken together, these studies suggest that children with SLI eventually develop the concept of conservation, but they are delayed in its acquisition.

These early studies of conservation in SLI were based on the idea that the core, underlying deficit in SLI is poor ability for symbolic representation (Kamhi, 1981; Morehead & Ingram, 1973). However, many studies focusing on symbolic deficits failed to show clear-cut evidence for a relation between language age and conservation performance (e.g., Kamhi, 1981). These early studies compared the performance of children with SLI to that of typically developing controls in terms of the number of same–different judgments and developmental stage scores. These studies did not focus on the way in which children with SLI conceptualized the conservation tasks themselves.

More recent studies of conservation in typically developing children have focused on how the concept of conservation is represented and how these representations change during developmental transitional states (e.g., Church, 1999). In this context, mental representation refers to ways in which children think about the conservation tasks. Children's representations are typically investigated by asking the children to explain their thinking about the conservation task after the fact. The explanations that children express in both speech and gesture can be coded. An example of an explanation expressed in speech would be "Because you poured that one"; an example of an explanation expressed in gesture would be a motion imitating pouring. When learning the concept of conservation, typically developing children progress from nonconserving performance (always judging the quantities as "different") to conserving performance (always judging the quantities as the "same"). In between nonconserving and conserving states, typically developing children display transitional knowledge of conservation before reaching fully conserving performance (Church & Goldin-Meadow, 1986). During transitional states, children's judgments may vary from task to task, and children may sometimes express more advanced explanations, and sometimes developmentally earlier explanations. Furthermore, children sometimes express different explanations in speech and gesture on the same task (Church & Goldin-Meadow, 1986).

One account of the transition from nonconservation to conservation in typically developing children is a progressive shift from perceptual to more "cognitive" representations (Piaget, 1965; Schultz, 1998). The basic idea is that in order to develop a strong concept of conservation, the child has to move away from focusing on the perceptual attributes of the current situation (e.g., the height of the glass) and be able to refer to an internal representation or memory of what happened before (e.g., the initial equality or the transformation). It is impossible to tell for certain if a tall skinny glass has the same amount of liquid as a short wide one without referring back to an internal representation of the initial equality of the liquid and the type of transformation that was conducted (e.g., pouring liquid from one glass to another). To successfully perform the task, one has to repress the "incorrect" or misleading external perceptual cues and refer back to an internal representation of the initial equality. Therefore, continued reliance on external features and lack or weakness of internal representations could be one account of delay in acquiring conservation.

This view is compatible with Zhang's (1997) discussion of the interplay of internal and external representations in problem solving in typical adults. This hypothesis is also consistent with recent parallel distributed processing computer modeling conducted by Shultz (1998). The networks started out basing their judgments on external perceptual features such as length, but as the networks gradually constructed a representation of transformation knowledge (i.e., an internal representation), a sudden shift from nonconserving to conserving performance was observed.

Rethinking conservation tasks in terms of both the external perceptual features of the task and the internal mental representation of the transformation may have implications for understanding the delayed acquisition of conservation in children with SLI. Across a number of domains, there is evidence to suggest that the mental representations of children with SLI may differ from those of their peers (Bishop, 2000). For example, studies suggest that (a) phonological representations may be holistic or less precise in children with SLI (Dollaghan, 1998), (b) semantic representations of children with SLI may contain less detail than those of typical peers (McGregor & Appel, 2002; McGregor, Newman, Reilly, & Capone, 2002), and (c) representations of syntactical constructs may be weak in children with SLI (Evans, 2002). The question remains whether weak or imprecise representations in children with SLI are specific to language tasks or extend to nonverbal cognitive tasks as well. Johnston (2004) presented some evidence that the difficulty children with SLI experience with nonverbal cognitive tasks may be due to difficulty in forming internal representations of the task in question. If the developmental trajectory in successfully solving conservation tasks is such that children move from focusing primarily on external features to focusing on internal mental representations as the internal representations gradually develop (Piaget, 1965; Schultz, 1998), then if children with SLI have difficulty building internal representations (Inhelder, 1963; Johnston, 2004) and rely mostly on external cues, this could account for their delayed performance.

On the basis of evidence from children's speech and gestures, Evans et al. (2001) have suggested that children with SLI may be in an extended transitional state with respect to conservation. That is, they may continue to activate multiple ideas, including both developmentally earlier and later ideas about conservation tasks, for an extended period of time, relative to their typically developing peers. However, Evans et al. did not directly examine whether children with SLI rely more on external perceptual representations rather than internal mental representations to solve the conservation tasks. Before one can assume that delayed conservation performance in children with SLI is a manifestation of weak internal representations, we need to look directly at whether children with SLI are relying less on such internal representations.

Based on this view, it was hypothesized that children with SLI focus less on internal representations and more on external features in conservation tasks, and, therefore, they are slow to acquire the concept of conservation. To test this hypothesis, we coded the explanations that children with SLI expressed in speech and gesture on conservation tasks. We classified the explanations into two categories: external ones, which focus on external, perceptual, currently present features of the task, and internal ones, which focus on internal representations of what happened before. It was predicted that children with SLI would (a) exhibit difficulties in correctly judging amount in the conservation tasks, as compared to a group of chronological age-matched (CA) controls, (b) express more external and fewer internal explanations of their thinking when compared with typically developing CA peers, and (c) express comparable rates of internal and external explanations when compared with younger conservation judgment-matched (CM) controls.

Method

Participants

Twenty-nine children participated in the study, including 12 children with SLI (ages 7;0—10;5) and 17 typically developing controls (ages 5;4–10;9). All children met the following inclusion criteria: (a) passed a pure-tone audiometric screening at 20 dB HL at 500, 1000, 2000, and 4000 Hz; (b) had nonverbal intelligence at or above 85 as measured by the Columbia Mental Maturity Scale (Burgemeister, Hollander Blum, & Lorge, 1972), the Leiter International Performance Scale (Roid & Miller, 1997), or the Test of Nonverbal Intelligence (Brown, Sherbenou, & Johnsen, 1990); (c) came from English-speaking monolingual homes; and (d) did not have oral and speech motor disabilities. Children were excluded if they had any of the following conditions based on parent report: emotional or behavioral disturbances, cognitive delay, motor deficits, or frank neurological signs including seizure disorders or use of seizure medications. In the SLI group, 4 children were African American, and 8 were White. All of the typically developing children were White.

Children with SLI were administered the expressive and receptive subtests of the Clinical Evaluation of Language Fundamentals—Revised (CELF–R; Semel, Wiig, & Secord, 1987). A criterion of an expressive language score one standard deviation below the standard mean or lower in standard scores was used for inclusion in the SLI group. Nine of the 12 children with SLI also exhibited receptive deficits, with receptive language scores on the CELF–R one standard deviation below the standard mean or lower in standard scores. None of the typically developing children received speech and language or special education services, and all of them were placed in age-appropriate classrooms. To screen the language

Table 1. Child identification code, group, age in months, gender, standard scores for nonverbal intelligence (IQ), expressive language score (ELS), Oral Directions receptive subtest (OD), and receptive language score (RLS), and percentage of words recalled on the Competing Language Processing Task (CLPT) for children in the specific language impairment (SLI) and chronological age-matched (CA) groups.

Child	Group	Age	Gender	IQ	ELS[d]	OD[e]	RLS[f]	CLPT[g]
S1	SLI	84	M	92[a]	59	7	76	2.4
S2	SLI	85	M	116[a]	82	4	70	0
S3	SLI	88	M	89[a]	64	6	83	2.4
S4	SLI	102	M	108[a]	62	5	80	28.6
S5	SLI	102	M	102[a]	62	9	65	0
S6	SLI	105	F	107[a]	76	5	91	19
S7	SLI	113	F	97[a]	62	8	50	2.4
S8	SLI	114	F	103[a]	74	4	78	54.8
S9	SLI	116	F	100[a]	62	3	54	33.3
S10	SLI	122	M	115[b]	78	4	89	38.1
S11	SLI	124	F	95[b]	64	8	74	21.4
S12	SLI	125	M	105[c]	72	11	97	47.6
M		106.67		102.42	68.08*	6.17*	75.85	20.8*
SD		14.87		8.43	7.80	2.44	14.22	19.7
T1[h]	CA	77	F	107[a]	91	9	—	26.2
T2	CA	86	F	116[a]	130	15	—	45.2
T3[h]	CA	88	F	98[a]	97	4	87	33.3
T4[h]	CA	103	M	112[a]	106	14	—	54.8
T5[h]	CA	103	F	99[a]	93	9	—	35.7
T6	CA	104	F	110[a]	104	9	—	47.6
T7[h]	CA	109	M	112[a]	99	10	—	43
T8	CA	116	M	109[a]	112	11	—	69
T9	CA	116	F	111[a]	115	14	—	66.7
T10	CA	125	F	111[c]	91	11	—	66.7
T11	CA	125	F	93[b]	118	11	—	59.5
T12	CA	129	F	102[b]	106	9	—	61.9
M		106.75		106.67	105.17*	10.5*		50.8*
SD		16.62		7.01	12.0	3.0		14.4

Note. Dashes indicate that test was not administered.

[a]Standard score from the Columbia Mental Maturity Scale (M = 100, SD = 15). [b]Standard score from the Leiter International Brief IQ (M = 100, SD = 15). [c]Standard score from the Test of Nonverbal Intelligence (M = 100, SD = 15). [d]Clinical Evaluation of Language Fundamentals: Expressive Language score (M =100, SD =15). [e]Clinical Evaluation of Language Fundamentals: Oral Directions receptive subtest score (M = 10, SD = 3). [f]Clinical Evaluation of Language Fundamentals: Receptive Language subtest score (M = 100, SD = 15). [g]Words recalled on Competing Language Processing Task. [h]Child was also in the conservation judgment-matched (CM) group.

*p < .05, two-tailed.

skills of the typically developing children, we administered the three expressive subtests of the CELF–R and one receptive subtest, the Oral Directions subtest. If the typically developing children failed the Oral Directions screening (subtest score one standard deviation below the mean, subtest score of 7), the entire receptive battery was administered. Fifteen of the 17 typically developing children received subtest standard scores of 8 or higher in the Oral Directions receptive subtest; however, 2 children in this group received standard scores below 7 (T3 and T17). These two typically developing children were administered the remaining two subtests of the CELF–R to ensure that receptive language abilities were within normal limits. These children's total receptive language scores of 97 and 87 were within the normal range. To confirm SLI or typical language status, all of the children were also administered a verbal working memory task, the Competing Language Processing Task (CLPT; Gaulin & Campbell, 1994). This task has been shown to effectively distinguish between children with and without language disorder (Ellis Weismer & Thordardottir, 2002; Rodekohr & Haynes, 2001). See Table 1.

Two control groups were included in this study: a chronological age-matched group (CA) and a conservation judgment-matched group (CM). Each of the 12 children with SLI had an age-matched, typically developing counterpart (matched within +/– 7 months). These typically developing children formed the first control group, the CA group. The SLI and CA groups' standard scores for the expressive language scores were significantly different, $t(22) = 8.00$, $p < .05$, $\eta^2 = 1.00$, as were their standard scores for the Oral Directions receptive subtest, $t(22) = 3.93$, $p < .05$, $\eta^2 = .41$. The SLI and CA groups did not differ significantly in nonverbal IQ, $t(22) = 1.34$, $p = .19$, $\eta^2 = .08$; however, according to Mervis and Robinson (1999), p values higher than .5 should be obtained to convincingly show that the groups are well matched; therefore, IQ was entered as a covariate in the SLI versus CA analyses. The SLI group differed significantly from the CA group in percentage of words recalled on the CLPT, $t(22) = 4.25$, $p < .05$, $\eta^2 = .45$.

A second group of 10 of the 12 children with SLI (SLI-C group; ages 7;1–10;5) were matched to typically developing children solely based on conservation knowledge as evidenced by judgments (see Table 2). The two groups were matched on their number of same judgments in the conservation task. This group of typically developing children formed the second control group, the CM group (ages 5;4–9;1). Five of the 10 children in the CM group were also in the CA group, but were matched to different children with SLI based on their same judgments in the conservation task. The remaining 5 CM children were not part of the CA group and served as matches for the remaining children with SLI. The overlap in children in the two control groups, CA and CM, did not violate assumptions of statistical independence, because these two groups were not directly compared with each other or entered into the same statistical analysis. Instead, the CA group was compared with the SLI group, and the CM group was compared with the SLI-C group. No individual child was included twice in any statistical analysis. Thus, the group comparisons were independent. See Ellis Weismer and Hesketh (1996) for a similar matching strategy.

The language abilities for the SLI-C and CM groups did not differ significantly. The SLI-C group did not differ significantly from the CM group in raw score on the Formulated Sentences subtest of the CELF–R (SLI-C $M = 31.50$, $SD = 5.02$; CM $M = 30.90$, $SD = 12.99$), $t(11.63) = 1.40$, $p = .89$, $\eta^2 = 0$ (unequal variances assumed), raw score on the Recalling Sentences subtest of the CELF–R (SLI-C $M = 47.00$, $SD = 10.21$; CM $M = 54.7$, $SD = 12.08$), $t(18) = -1.54$, $p = .14$, $\eta^2 = .12$, or the raw score of the Oral Directions receptive subtest of the CELF–R (SLI-C $M = 11.40$, $SD = 5.44$; CM $M = 11.40$, $SD = 6.04$), $t(18) = 0.14$, $p = 1.0$, $\eta^2 = 0$. The SLI-C and CM groups also did not differ significantly in percentage of words recalled on the CLPT (SLI-C $M = 24.50$, $SD = 19.61$; CM $M = 31.60$, $SD = 18.43$), $t(18) = 0.84$, $p = .41$, $\eta^2 = .04$. Interestingly, this indicates that although the CM group was not selected to match the SLI group on measures of language and verbal working memory, the two groups had similar language and verbal working memory abilities. This suggests that reasoning in the conservation task, language abilities, and verbal working memory are closely related.

Table 2. Child identification code, group membership, number of same judgments (Jud) on the conservation tasks, age in months, standard scores for nonverbal intelligence (IQ), expressive language score (ELS), Oral Directions receptive subtest (OD), receptive language score (RLS), and percentage of words recalled on the Competing Language Processing Task (CLPT) for children in the specific language impairment (SLI-C) and conservation judgment-matched (CM) groups.

Child	Group	Jud	Age	IQ	ELS[d]	OD[e]	RLS[f]	CLPT[g]
S9	SLI-C	0	116	100[a]	62	4	54	33.3
S2	SLI-C	2	85	116[a]	82	6	70	0
S12	SLI-C	2	125	105[c]	72	9	97	47.6
S8	SLI-C	5	114	103[a]	74	5	78	54.8
S4	SLI-C	6	102	108[a]	62	8	80	28.6
S11	SLI-C	6	124	95[b]	64	4	74	21.4
S7	SLI-C	7	113	97[a]	62	3	50	2.4
S5	SLI-C	8	102	102[a]	62	4	65	0
S6	SLI-C	8	105	107[a]	76	8	91	19
S10	SLI-C	8	122	115[b]	78	11	89	38.1
M		5.2	110.8	104.8	69.4	6.20	74.8	24.52
SD		2.9	12.5	7.0	7.83	2.66	15.5	19.60
T14	CM	0	66	111[a]	95	11	—	0
T16	CM	1	76	113[a]	93	10	—	35.7
T15	CM	2	69	120[a]	106	11	—	0
T13	CM	5	64	128[a]	124	14	—	40
T1[h]	CM	6	77	107[a]	91	9	—	26.2
T3[h]	CM	6	88	98[a]	97	4	87	33.3
T17	CM	7	76	127[a]	95	5	97	47.6
T4[h]	CM	8	103	112[a]	106	14	—	54.8
T5[h]	CM	8	103	99[a]	93	9	—	35.7
T7[h]	CM	8	109	112[a]	99	10	—	43
M		5.1	83.1	114.9	99.9	9.70		31.6
SD		3.03	16.6	11.14	9.93	3.27		18.4

Note. Dashes indicate that test was not administered.

[a]Standard score from the Columbia Mental Maturity Scale (*M* = 100, *SD* = 15). [b]Standard score from Leiter International Brief IQ (*M* = 100, *SD* = 15). [c]Standard score from the Test of Nonverbal Intelligence (*M* = 100, *SD* = 15). [d]Clinical Evaluation of Language Fundamentals: Expressive Language score (*M* = 100, *SD* = 15). [e]Clinical Evaluation of Language Fundamentals: Oral Directions receptive subtest score (*M* = 10, *SD* = 3). [f]Clinical Evaluation of Language Fundamentals: Receptive Language subtest score (*M* = 100, *SD* = 15). [g]Words recalled on Competing Language Processing Task. [h]Child was also in the chronological age-matched (CA) group.

Experimental Task

All children completed eight Piagetian conservation tasks: two liquid, two number, two length, and two mass. Children were presented the tasks in a fixed order as follows: liquid, number, length, and mass.[1] The protocol followed four steps for each task: (a) initial equality, (b) transformation, (c) judgment, and (d) explanation.

Initial equality. Each task began with the investigator presenting the child with two quantities with the same amount. In the case of liquid, the child saw two identical glasses; in the case of number, two identical rows of six checkers; in the case of length, two identical sticks; and in the case of mass, two identical balls of playdough. The investigator then asked the child the following questions while indicating the quantities by pointing. In the liquid tasks, the child was asked, "Is there more water in this glass, more water in this glass, or do they both have the same amount?" In the number task, the child was asked, "Are there more checkers here, more checkers here, or do they both have the same number?" In the length tasks, the child was asked, "Is this stick longer, is this stick longer, or are they both the same length?" Finally, in the mass tasks, the child was asked, "Is there more playdough here, more playdough here, or do they both have the same amount?" If the child did not agree that the initial amounts were the same, then changes were made to the items (e.g., more water was added to one of the glasses), and the child was again asked if the two amounts were the same. This phase was repeated until the child agreed that the two quantities were the same amount. All of the children answered the questions appropriately, and their behavior indicated that they understood the task and the questions.

Transformation. After establishing that the quantities were equal, the investigator performed a transformation to one of the items without changing the actual quantity. In the first liquid task, the water in one of the glasses was poured into a short wide glass; in the second liquid task, the water was poured into a tall skinny glass. In the first number task, one of the rows of checkers was spread out; in the second number task, one of the rows was moved into a circle shape. In the first length task, one of the sticks was moved over; in the second length task, one stick was moved perpendicular to the other, forming a T shape. In the first mass task, one of the balls of playdough was flattened out into a flat, wide pancake-like shape; in the second mass task, one of the balls of playdough was rolled out into a long, skinny sausage-like shape.

Judgment. Following the transformation, the children were asked the same questions they were asked in the initial equality phase (e.g., "Is there more water in this glass, more water in this glass, or do they both have the same amount?"). A child's judgment was regarded as conserving if the child indicated that the amounts were the same following the transformation. A child's judgment was regarded as nonconserving if the child indicated that the amounts were different following the transformation.

Explanation. Finally, after the children gave their judgments, they were prompted to explain their thinking with a series of four questions: "How can you tell?" "How else can you tell?" "Is there any other reason?" and "Anything else you can think of?" The investigator then moved the items back to the initial equality state, and moved on to the next task. Because each child completed eight tasks, he or she was given a chance to give a total of 32 explanations. Children did not, however, give explanations after all of the prompts. Children with SLI gave an average of 12.33 explanations (148 in total), and typically developing children an average of 12.00 explanations (204 in total).

Coding Judgments

Children's verbal responses for the judgment phase of the experimental task were coded as either same or different to determine whether the children were exhibiting conserving reasoning.

Coding Explanations

The experimental tasks were recorded on both video- and audiotape. Children's verbal responses and accompanying gestures were coded separately. All of the children's utterances following each experimenter prompt were transcribed and coded using Church and Goldin-Meadow's (1986) conservation coding system. Verbal responses were transcribed from the audiotapes. Gestured responses were transcribed from the videotapes with the sound turned off. Children's hand movements were coded for explanation types based on shape, orientation, placement, and motion of the hand(s).

Each verbal and gestured explanation could receive one or more of the following codes: description, comparison, missed compensation, compensation, identity, identity by counting, one-to-one correspondence, initial equality, transformation, reversibility, and add–subtract. Definitions and examples of each explanation type are presented in Table 3. In addition, as seen in Table 3, the Church and Goldin-Meadow (1986) system was refined to include one additional category: general rule—hypothetical.

Each verbal and gestured response after the four experimenter prompts was then classified as either reflecting a focus on external features or internal representations

[1]One child received the tasks in a different order. This child's task order was as follows: liquid, length, number, mass.

Table 3. Examples of explanation types expressed in speech and gesture by children in this study.

Explanation type	Definition	Verbal example	Gesture example (handshape/placement/motion/meaning)	Type: external or internal
Description	Focus on one attribute of one task item, such as height	"Because it's taller"	1. Right hand neutral hand shape/Side of tall glass, at top edge/No motion/Height of tall glass	External
Comparison	Focus on one attribute of both task items	"Because this is low and that's higher"	1. Left hand neutral hand shape/By rim of untransformed glass/Moves to rim of transformed glass/Height of untransformed and transformed glasses	External
Compensation	Focus on two compensating dimensions of one or both task items (e.g., skinny but tall, short but wide)	"This one is skinnier and it goes higher"	1. Left hand point/Water level of short glass/Traces around glass/Height and width of transformed glass	External
Missed compensation	Focus on two different but noncompensating attributes of one or both task items (e.g., skinny and small, short and big)	"This one is wider and this one is this one is smaller"	1. Both hands, neutral handshapes/Endpoints of playdough "sausage"/No motion/Length of transformed playdough 2. Right hand point/On top of playdough sausage/No motion/Height of transformed playdough	External
One-to-one correspondence	Each checker in untransformed row has a counterpart in transformed row	"Cause each one has a partner"	1. Both hands, neutral hand shapes/Each checker in both rows/Traces from each checker in transformed row to corresponding one in untransformed row/One-to-one correspondence	External
Identity by counting or number	Focus on counting, number, or measuring in the present situation	"And you can count your head how much there is"	1. Left hand neutral handshape/Over checkers in transformed row/Points to each checker one by one/Count	External
Initial equality	Focus on initial equality of the quantities	"Because before"	No cases in this data set	Internal
Add–subtract	Nothing was added or taken away	"Cause there's no adding"	No cases in this data set	Internal
Transformation	Focus on the transformation that was conducted	"Easy, you just move them"	1. Left hand C shape/Above the transformed glass/Pouring motion/Pour into	Internal
Reversibility	Focus on the reversibility of the transformation	"… and move them back"	1. Both hands, neutral hand shapes/Endpoints of the transformed stick/Moves back to initial position/Reversibility (also description of length)	Internal
General rule—Hypothetical	Focus on attributes combined with information about general ways in which the attributes interact	"This is skinnier and skinnier stuff gets <mo> it higher up"	Only possible in speech. If the child gestured to the attributes, the meaning was coded as *description*, *comparison*, *compensation*, or *missed compensation* (see external explanations)	Internal

according to the following principles: (a) responses that focused on only the external perceptual features of the task (i.e., features that were present at the time the children were explaining their judgments) were coded as external and (b) responses that focused at least partly on mental internal representations of the task (i.e., features that were not present at the time children were explaining their judgments) were coded as internal. The following paragraphs describe how the explanation types from Church and Goldin-Meadow's (1986) system were classified into external and internal categories.

External responses reflect a focus on external features of the task. The following explanation types were coded as external: *description, comparison, compensation, missed compensation, identity by counting,* and *one-to-one correspondence*. Table 3 presents examples of the explanation types. In description, comparison, compensation, and missed compensation the focus is on the attributes of the task items before the child, such as height and width. In description, the focus is on one attribute of one task item (e.g., height); in comparison, on one attribute of both task items; in compensation, on two compensating dimensions of one or both task items (e.g., tall but skinny, short but wide); and in missed compensation, on two different but noncompensating attributes of one or both task items (e.g., tall and big). Identity by counting reflects a focus on counting the objects before the child. One-to-one correspondence is only possible in the number task, and the focus is on the fact that each checker in the transformed row has a counterpart in the untransformed row. If a response included external explanation types only, it was coded as external.

Internal responses reflect a focus on features of the task that were not present at the time children were explaining their judgments. The following explanation types were coded as internal: *initial equality, transformation, reversibility, add–subtract,* and *general rule—hypothetical*. In initial equality, the focus is on the state of the quantities before the transformation (e.g., the two glasses of water were exactly the same before one of them was poured in a glass of different type); in transformation, the focus was on the change that was conducted (e.g., water was poured to a new glass of different shape); in reversibility, the focus was on the reversibility of the change (e.g., water could be poured back into the original glass of same shape); and in add–subtract, the focus was on the fact that nothing was added or taken away (e.g., no additional water was added to the new glass from the pitcher). General rule—hypothetical explanations focus on attributes, but the attribute information was combined with a general rule about how the attributes behave (e.g., in general, when a glass is wider, the water level is lower than if the glass is skinnier). If a response included any of the internal explanation types, it was coded as internal.

Reliability

To assess reliability, we randomly selected 17% of the children, including 2 of the 12 children with SLI and 3 of the 17 typically developing children (including children from both CA and CM groups). A second coder recoded their explanations in gesture and speech. Agreement for coding verbal responses as internal or external was 94%, and agreement for coding gestured responses as internal or external was 86%. In addition, agreement was calculated separately for external and internal responses. It was 94% for external verbal responses, 97% for internal verbal responses, 86% for external gestured responses, and 88% for internal gestured responses.

Results

Same Judgments

The number of same judgments was calculated in order to investigate whether, consistent with previous findings, the children with SLI exhibited difficulties in the conservation task. Controlling for nonverbal IQ, the SLI group expressed significantly fewer same judgments than the CA group (SLI $M = 4.50$, $SD = 3.12$; CA $M = 7.67$, $SD = 0.78$), $F(1, 21) = 12.52$, $p < .05$, $\eta^2 = .37$. This suggests that children in the SLI group did in fact exhibit significant difficulty in the conservation task relative to their age-matched peers.

Explanations

SLI and CA groups. We next investigated the nature of the explanations expressed in speech and gesture by children in the SLI and CA groups. For each individual, we calculated the proportion of total explanations that were internal for each modality. The data are presented in Figure 1. Nonverbal IQ was used as a covariate. Children with SLI produced proportionately fewer internal explanations in the verbal modality, compared with their age-matched peers, $F(1, 21) = 5.88$, $p < .05$, $\eta^2 = .22$. However, children in the two groups produced comparable proportions of internal explanations in gesture, $F(1, 21) = 0.58$, $p = .45$, $\eta^2 = .03$.

SLI-C and CM groups. We also analyzed the proportion of internal explanations in each modality for the SLI-C and CM groups. The data are presented in Figure 2. Children in the SLI-C group produced a comparable proportion of verbal explanations that were internal, compared with their judgment-matched peers, $F(1, 17) = 0.93$, $p = .35$, $\eta^2 = .05$, and also produced a comparable proportion of gestured explanations that were internal, compared with their judgment-matched peers, $F(1, 17) = 0.04$, $p = .85$, $\eta^2 = 0$.

Figure 1. Mean proportion of total explanations that were internal, calculated separately for speech and gesture, for children in the specific language impairment (SLI) and chronological age-matched (CA) groups. The error bars represent standard errors.

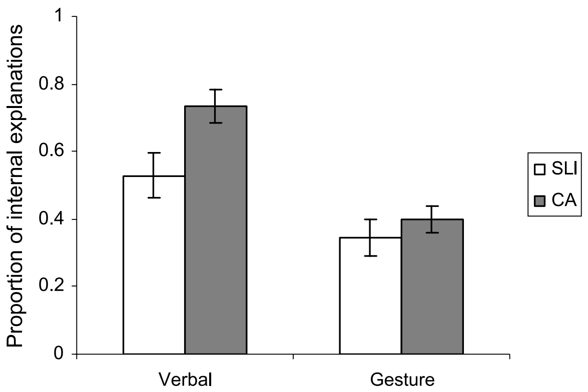
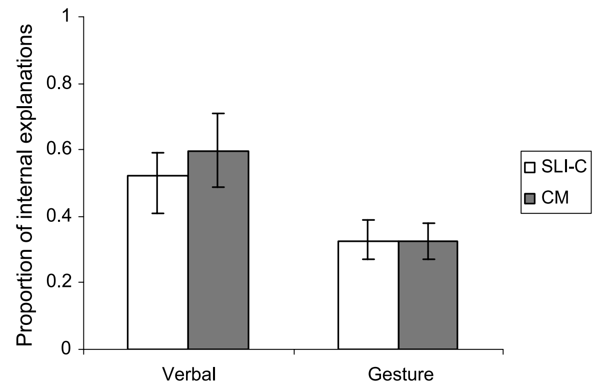


Figure 2. Mean proportion of total explanations that were internal, calculated separately for speech and gesture, for children in the specific language impairment (SLI-C) and conservation judgment-matched (CM) groups. The error bars represent standard errors.



We also investigated whether the two groups expressed internal explanations at similar rates when their conservation judgments denoted conserving thinking. For each child, we calculated the proportion of internal explanations expressed when the judgment was a conserving same judgment and when the judgment was a nonconserving different judgment. This was done for speech and gesture separately. Figures 3 and 4 present these data. Only children who exhibited partially conserving knowledge (i.e., expressed a combination of same and different judgments) could be included in this analysis. This resulted in 5 children with SLI and 5 CM controls. We conducted a Group × Modality × Judgment analysis of variance with proportion of internal explanations as the dependent variable.

The children with SLI did not differ from the judgment-matched controls in any significant way. The main effect of group was not significant, $F(1, 10) = 0.08$, $p = .78$, $\eta^2 = .01$, suggesting that, overall, the proportions of internal explanations expressed in both speech and gesture were similar for both groups. The Group × Modality interaction was also not significant, $F(1, 10) = 1.08$, $p = .32$, $\eta^2 = .10$, suggesting that the two groups did not differ in the proportions of internal explanations expressed in speech and in gesture. The three-way interaction of Group × Modality × Judgment did not reach significance either, $F(1, 10) = 0.13$, $p = .72$, $\eta^2 = .01$.

The significant main effect of judgment, $F(1, 10) = 29.36$, $p < .05$, $\eta^2 = .75$, indicated that when the children expressed same judgments, they were far more likely to express internal explanations than when they expressed different judgments. This was the case for both children with SLI and their peers; the Group × Judgment interaction was not significant, $F(1, 10) = 1.67$, $p = .23$, $\eta^2 = .14$, suggesting that children in both groups were likely to express internal explanations when their judgment was

Figure 3. Mean proportion of internal explanations when the judgment was either conserving (same) or nonconserving (different), calculated separately for speech and gesture, for children in the SLI-C group. The error bars represent standard errors.

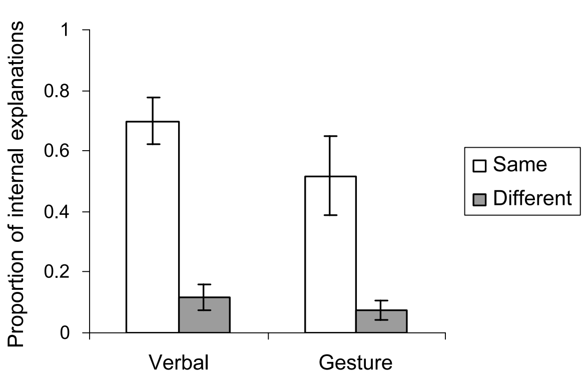
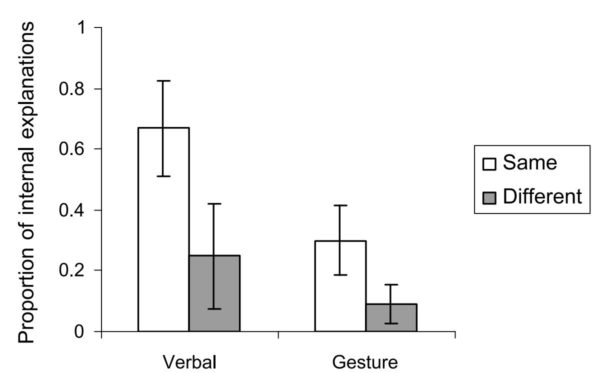


Figure 4. Mean proportion of internal explanations when the judgment was either conserving (same) or nonconserving (different), calculated separately for speech and gesture, for children in the CM group. The error bars represent standard errors.



same and unlikely to express internal explanations when their judgment was different.

The significant main effect of modality, $F(1, 10) = 6.53$, $p < .05$, $\eta^2 = .40$, indicated that in both groups, the proportion of internal explanations was higher in speech than in gesture. The Modality × Judgment interaction did not reach significance, $F(1, 10) = 3.26$, $p = .10$, $\eta^2 = .25$.

Correlations

To further explore the association between language testing, verbal working memory, and performance in the conservation task, we also investigated correlations between scores on the CELF–R Formulated Sentences, Recalling Sentences, and Oral Directions subtests; verbal working memory score from the CLPT; number of same judgments; proportion of internal explanations expressed in speech; and proportion of internal explanations expressed in gesture for the SLI-C and CM groups. This was done only for the SLI-C and CM groups because the CA group was close to ceiling in judging the quantities (i.e., most children in the CA group judged the quantities in all of the tasks correctly as the same). Table 4 presents Pearson's correlations among these variables for the SLI-C and CM groups. For both groups, a significant correlation between proportion of internal explanations expressed in speech and number of same judgments was observed, SLI-C $r = .79$, $p < .05$; CM $r = .92$, $p < .05$. Interestingly, we found that the CLPT verbal working memory scores were correlated with both number of same judgments, $r = .76$, $p < .05$, and proportion of internal explanations expressed in gesture, $r = .69$, $p < .05$, for the CM group, but for the SLI-C group, CLPT was not significantly correlated with any of the conservation measures.

Table 4. Pearson's correlations between Formulated Sentences (FS) subtest score, Recalling Sentences (RS) subtest score, Oral Directions (OD) receptive subtest score, Competing Language Processing Task (CLPT), number of same judgments on the conservation task (Jud), proportion of internal explanations expressed in speech on the conservation task (Int Sp), and proportion of internal explanations expressed in gesture on the conservation task (Int Ges) for the SLI-C and CM groups.

Variable		FS[a]	RS[b]	OD[c]	CLPT[d]	Jud	Int Sp	Int Ges
SLI-C	FS	—	.40	.59	.31	.12	.06	.21
	RS		—	.15	−.13	.54	.46	.14
	OD			—	.72*	.02	−.05	.01
	CLPT				—	−.26	−.39	−.24
	Jud					—	.79*	.51
	Int Sp						—	.48
	Int Gest							—
		FS	RS	OD	CLPT	Jud	Int Sp	Int Ges
CM	FS	—	.50	.36	.74*	.68	.44	.59
	RS		—	.45	.29	.41	.47	.11
	OD			—	.18	.18	.26	.54
	CLPT				—	.76*	.54	.69*
	Jud					—	.92*	.66
	Int Sp						—	.51
	Int Gest							—

[a]Clinical Evaluation of Language Fundamentals: Formulated Sentences subtest score. [b]Clinical Evaluation of Language Fundamentals: Recalling Sentences subtest score. [c]Clinical Evaluation of Language Fundamentals: Oral Directions receptive subtest score. [d]Words recalled on Competing Language Processing Task.

*$p < .05$.

Discussion

Consistent with previous studies, the present results indicate that children with SLI exhibit difficulty in conservation tasks. Children with SLI expressed significantly fewer same judgments when compared with their age-matched peers. The children with SLI did not differ from the younger conservation judgment-matched peers in raw language subtest scores, nor on words recalled on the CLPT, suggesting that conservation knowledge, language skills, and verbal working memory are closely related.

It was hypothesized that children with SLI have difficulty in conservation tasks because they have weak internal mental representations of the conservation task, and therefore rely more on external representations of perceptual features of the task objects. This hypothesis was supported in that the SLI group expressed a smaller proportion of internal explanations in speech as compared with the CA group. When the children with SLI were compared with a younger conservation knowledge-matched group, the CM group, no differences were found in the distribution of explanations. Furthermore, we observed that when children in both groups judged the quantities in the task correctly, they were likely to provide internal explanations in both speech and in gesture. These results suggest that children with SLI continue to have weak internal representation of the concept of conservation, similar to those of younger children, until the late elementary school years.

Furthermore, because the CM group did not differ from the SLI-C group in their raw language or working memory scores, it appears that weak internal representations may be closely related to language and verbal memory skills. The relationship between language abilities and verbal working memory is not surprising. It is unclear from the data in this study, however, as to what is the direction of the relations among language, working memory, and development of conservation skills. It is possible, as has been suggested in the past (Kamhi, 1981; Morehead & Ingram, 1973) that a general representational ability underlies both language skills and internal representations of the conservation tasks. It is also possible that language skills mediate internal conservation knowledge, either in that the children need a certain level of language ability in order to express internal conservation explanations or in that children need a certain level of language ability to be able to have fully internal conservation representations. It is also possible that verbal working memory ability mediates the development of both language and internal conservation representations.

The present results could also be interpreted within the framework of limited processing capacity. It has been argued that limited processing capacity may underlie difficulties seen in SLI (Leonard, 1998). It is possible that children with SLI are slower and less efficient in processing the nonverbal elements of the conservation task and therefore have difficulty maintaining internal representations in working memory. This could lead to reliance on external features, which need not be held internally, when judging the quantities. Zhang (1997) has shown that individuals inappropriately rely on external features in problem solving when processing all solution possibilities exceeds their processing capacity. Similarly, inefficient processing in children with SLI might have caused them to rely on the external features. Interestingly, we found a correlation between verbal working memory span on the CLPT and performance on the conservation task for typically developing children, but not for children with SLI. Recent reevaluations of performance on working memory span tasks suggest that individual differences in children's performance on these tasks can be accounted for by the efficiency with which the processing operations, verbal and nonverbal, are executed, rather than individual differences in overall storage capacity (Towse, Hitch, & Hutton, 1998). The correlation between verbal working memory span and conservation performance, therefore, may suggest that efficiency of language (and potentially nonverbal) processing is linked to conservation performance in typically developing children. Performance on the CLPT verbal working memory span and conservation performance were, however, not correlated in children with SLI. This may indicate a qualitatively different approach to conservation tasks in children with SLI.

A possible explanation for this qualitatively different approach to conservation may be related to gesturing. Prior work has suggested that children with SLI may rely on gesture to augment their poor language skills (Evans et al., 2001). In the present study, we observed that the pattern of internal and external explanations in gesture differed from that observed in speech, and also differed from what was expected. It was expected that if children with SLI have weaker internal conservation representations that are comparable to younger children, they would express fewer internal and more external explanations as compared with CA peers in gesture as well as in speech. This was not case: Children with SLI did not differ from CA peers in the proportion of internal explanations expressed in gesture. Therefore, it is possible that children with SLI had internal representations comparable to CA peers but were not able express this knowledge in speech. However, children in all groups expressed more external and fewer internal explanations in gesture; the patterns were similar for the SLI groups and both control groups. If children with SLI had internal conservation representation comparable to age-matched peers but were able to only express this knowledge in gesture, then we should have found a greater proportion of internal explanations expressed in gesture for the SLI-C group than the CM group. Therefore, the data are the most consistent with the idea that, whereas external explanation types can be readily expressed in both speech and gesture, it is harder to express internal explanations in gesture. It is possible that greater reliance on gesture in communication in the children with SLI results in greater attention to external features and therefore leads to weaker internal representations. Consistent with this idea, prior work suggests that gesturing may promote a focus on external representations in typical children. When children were prohibited from gesturing on a set of conservation tasks, they provided more internal explanations than when they were allowed to gesture (Alibali, Kita, Bigelow, Wolfman, & Klein, 2001). Thus, a greater reliance on gestures may lead to a greater emphasis on the external perceptual features of the task. Reliance on gesture and a focus on external features may also explain the decoupling of verbal processing in the verbal working memory task and conservation performance found in children with SLI. A clinical implication of this finding is that promoting gesture as an augmentative medium of communication may lead to cognitive representations that are qualitatively different from those used when speech is relied on more heavily. Further investigations are needed to address whether gesturing plays a causal role in greater reliance on external features in children with SLI.

The present work suggests that children with SLI rely more on external features of conservation tasks, rather than generating detailed internal mental representations. These findings are consistent with work by Johnston and Ellis Weismer (1983), who suggested that children with SLI have difficulties with nonlinguistic representational processes, specifically generating, maintaining, or interpreting internal representations. Problems in generating, maintaining, or interpreting internal representations of the conservation task may explain the difficulties children with SLI exhibited on the conservation task in this study. Language abilities, processing capacity, or relying on gesturing to augment communication may be related to the development of internal representations in nonverbal tasks. One goal of future work should be to identify the mechanisms that underlie the deficits seen in children with SLI in generating strong internal mental representations of cognitive tasks.

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References

Alibali, M. W., Kita, S., Bigelow, L. J., Wolfman, C. M., & Klein, S. M. (2001). Gestures play a role in thinking for speaking. In C. Cavé, I. Guaïtella, & S. Santi (Eds.), *Oralité et gestualité: Interactions et comportements multimodaux dans la communication* [*Orality and gestuality: Multimodal interaction and behavior in communication*]. *Proceedings of the meeting of ORAGE 2001* (pp. 407–410). Paris: L'Harmattan.

Bishop, D. V. M. (1992). The underlying nature of specific language impairment. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 33,* 3–66.

Bishop, D. V. M. (2000). How does the brain learn language? Insights from the study of children with and without language impairment. *Developmental Medicine and Child Neurology, 42,* 133–142.

Brown, L., Sherbenou, R., & Johnsen, S. (1990). *Test of Nonverbal Intelligence—2*. Austin, TX: ProEd.

Burgemeister, B., Hollander Blum, L., & Lorge, I. (1972). *Columbia Mental Maturity Scales*. New York: Harcourt Brace Jovanovich.

Church, R. B. (1999). Using gesture and speech to capture transitions in learning. *Cognitive Development, 14,* 313–342.

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

Dollaghan, C. A. (1998). Spoken word recognition in children with and without specific language impairment. *Applied Psycholinguistics, 19,* 193–207.

Ellis Weismer, S. (1991). Hypothesis-testing abilities of language impaired children. *Journal of Speech and Hearing Research, 34,* 1329–1338.

Ellis Weismer, S., & Hesketh, L. J. (1996). Lexical learning by children with specific language impairment: Effects of linguistic input rate presented at varying speaking rates. *Journal of Speech and Hearing Research, 39,* 177–189.

Ellis Weismer, S., & Thordardottir, E. T. (2002). Cognition and language. In P. Accardo, A. Capute, & B. Rogers (Eds.), *Disorders of language development* (pp. 21–37). Timonium, MD: York Press.

Evans, J. L. (2002). Variability in comprehension strategy use in children with SLI: A dynamical systems account. *International Journal of Language & Communication Disorders, 37,* 95–116.

Evans, J. L., Alibali, M. W., & McNeil, N. M. (2001). Divergence of verbal expression and embodied knowledge: Evidence from speech and gesture in children with specific language impairment. *Language and Cognitive Processes, 16,* 309–331.

Gaulin, C., & Campbell, T. (1994). Procedure for assessing verbal working memory in normal school-age children: Some preliminary data. *Perceptual and Motor Skills, 79,* 55–64.

Inhelder, B. (1963). Observations sur les aspects operatifs de la pensee chez des enfants dysphasiques [Observations on the operational and figurative aspects of thought in dysphasic children]. *Problemes de Psycholinguistigue, 6,* 143–153.

Johnston, J. R. (2004, June). *Fearless and bold in following ideas wherever they lead (The Elisabeth Bates Memorial Lecture).* Presentation at the Twenty-Fifth Symposium on Research in Child Language Disorders, Madison, WI.

Johnston, J. R., & Ellis Weismer, S. (1983). Mental rotation abilities in language-disordered children. *Journal of Speech and Hearing Research, 26,* 397–403.

Johnston, J. R., & Ramstad, V. (1983). Cognitive development in preadolescent language impaired children. *British Journal of Disorders of Communication, 18,* 49–55.

Kamhi, A. G. (1981). Nonlinguistic symbolic and conceptual abilities of language impaired and normally developing children. *Journal of Speech and Hearing Research, 24,* 453–466.

Kamhi, A. G., Catts, H. W., Koenig, L. A., & Lewis, B. A. (1984). Hypothesis-testing and nonlinguistic symbolic abilities in language-impaired children. *Journal of Speech and Hearing Disorders, 49,* 169–176.

Leonard, L. B. (1998). *Children with specific language impairment*. Cambridge, MA: MIT Press.

McGregor, K. K., & Appel, A. (2002). On the relation between mental representation and naming in a child with specific language impairment. *Clinical Linguistics and Phonetics, 16,* 1–20.

McGregor, K. K., Newman, R. M., Reilly, R. M., & Capone, N. C. (2002). Semantic representation and naming in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 45,* 998–1014.

Mervis, C. B., & Robinson, B. F. (1999). Methodological issues in cross-syndrome comparisons: Matching procedures, sensitivity (Se) and specificity (Sp). *Monographs of the Society for Research in Child Development, 64,* 115–130.

Montgomery, J. W. (1993). Haptic recognition of children with specific language impairment: Effects of response modality. *Journal of Speech and Hearing Research, 36,* 98–104.

Morehead, D., & Ingram, D. (1973). The development of base syntax in normal and linguistically deviant children. *Journal of Speech and Hearing Research, 16,* 330–352.

Nelson, L. K., Kamhi, A. G., & Apel, K. (1987). Cognitive strengths and weaknesses in language impaired children: One more look. *Journal of Speech and Hearing Disorders, 52,* 36–43.

Piaget, J. (1965). *The child's conception of number*. New York: W. W. Norton.

Rodekohr, R. K., & Haynes, W. O. (2001). Differentiating dialect from disorder: A comparison of two processing tasks and a standardized language test. *Journal of Communication Disorders, 34,* 255–272.

Roid, G., & Miller, L. (1997). *Leiter International—Revised*. Wood Dale, IL: Stoelting.

Semel, E., Wiig, E., & Secord, W. (1987). *Clinical Evaluation of Language Fundamentals*. San Antonio, TX: The Psychological Corporation.

Schultz, T. R. (1998). A computational analysis of conservation. *Developmental Science, 1,* 103–126.

Siegel, L., Lees, A., Allan, L., & Bolton, B. (1981). Nonverbal assessment of Piagetian concepts in preschool children with impaired language development. *Educational Psychology, 1,* 153–158.

Siegler, R. S. (1981). Developmental sequences within and between concepts. *Monographs of the Society for Research in Child Development, 46,* 1–74.

Towse, J. N., Hitch, G. J., & Hutton, U. (1998). A reevaluation of working memory capacity in children. *Journal of Memory and Language, 39,* 195–217.

Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Science, 21,* 179–217.

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