

Verbal and Spatial Analogical Reasoning in Deaf and Hearing Children: The Role of Grammar and Vocabulary

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The extent to which cognitive development and abilities are dependent on language remains controversial. In this study, the analogical reasoning skills of deaf and hard of hearing children are explored. Two groups of children (deaf and hard of hearing children with either cochlear implants or hearing aids and hearing children) completed tests of verbal and spatial analogical reasoning. Their vocabulary and grammar skills were also assessed to provide a measure of language attainment. Results indicated significant differences between the deaf and hard of hearing children (regardless of type of hearing device) and their hearing peers on vocabulary, grammar, and verbal reasoning tests. Regression analyses revealed that in the group of deaf and hard of hearing children, but not in the hearing group, the language measures were significant predictors of verbal analogical reasoning, when age and spatial analogical reasoning ability were controlled for. The implications of these findings are discussed.

Language has long been considered an important underpinning to the reasoning process. Vygotsky (1978) considered that language becomes a tool for thinking when the early social speech of children is transformed to inner speech—self-directed verbalizations. As Akamatsu, Mayer, and Hardy-Braz (2008) state “Since the social language forms the foundation for the inner language, the quality of the language used in social interactions as well as the nature of these interactions, has a direct bearing on the quality of the language and thought that becomes the substance of inner speech.” (p. 136). Given that the majority of deaf¹ children,

who have hearing parents, are at risk of delayed language development if they are not exposed to sign language in early childhood (Mayberry and Lock, 2003; Mayberry, Lock, & Kazmi, 2002), it would be predicted that they would also have poor development of inner speech and consequently difficulties in developing reasoning skills. Support for the importance of the role of inner speech in reasoning comes from evidence that higher levels of inner speech have been associated with better problem-solving skills in hearing children (Berk, 1992). Recently, a dual systems theory of problem solving has been developed (Carruthers, 2008) that incorporates the function of inner speech. System 1 comprises a number of fast, unconscious processes that operate in parallel and therefore would not be considered associated with inner speech to any great extent. In contrast, system 2 is slow, serial, and conscious, with inner speech playing a role in its operation. Natural language would play an important constitutive role in system 2 thought processes including reasoning.

As noted above, language development is often delayed in deaf children of hearing parents and therefore the investigation of their reasoning processes can increase understanding of the relationship between language and reasoning. Given that higher levels of inner speech have been found to be associated with better problem-solving skills, and that deaf children of hearing parents experience difficulty developing private speech (the precursor to inner speech: speech that is spoken or signed aloud but serves no social

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function and is used to guide and regulate the actions of the speaker, e.g., Jamieson, 1995), it could be expected that these deaf children will have difficulty solving problems, particularly those with a high verbal loading.

Research on the cognitive abilities of deaf children has produced inconsistent findings. Differences in working memory, particularly for verbal material, have commonly been found and appear to be related to the use of memory strategies such as rehearsal (Marschark, Lang, & Albertini, 2002). Following a review of the literature, Mayberry (2002) states that “The delayed and depressed language development of deaf children, as a group, is not caused by, and does not cause, general intellectual deficiencies in cognitive domains that function independent of language.” (p. 100). She therefore concludes that language and nonlinguistic cognitive development are functionally separable to a large degree.

In terms of reasoning skills in deaf individuals, Ottem (1980) concluded that these individuals’ performance is at a disadvantage with respect to that of age-matched hearing people in tasks requiring simultaneous attention to two or more elements—such as the height of water in a container and the container’s shape. Marschark (2003) also notes that deaf individuals tend to process specific items individually rather than attend to or recognize the relations between items. Analogical reasoning fundamentally relies on such relational processing, establishing a correspondence between one set of relations (for instance, the oppositional relation emergent in the conceptual pair “happy–sad”) and another (the same oppositional relation emerging in the pair “healthy–ill”, Goswami, 1991).

Surprisingly few studies of deaf children have focused explicitly on analogical reasoning. One relevant study by Bandurski and Galkowski (2004) compared verbal, arithmetic, and spatial analogical reasoning skills of deaf children born to hearing parents (hence not exposed to sign language in infancy), with the reasoning skills of deaf children born to deaf parents (hence exposed to sign language in infancy), and to those of hearing children. The early language-deprived children, that is those deaf children born to hearing parents, showed poorer verbal

analogical reasoning than the other two groups but their arithmetic and spatial analogical reasoning levels were similar to those of the other two groups. This suggests that early access to language, irrespective of language mode (signed or spoken), is the prerequisite for the development of verbal analogical reasoning skills. However, there is some earlier contradictory evidence regarding deaf children’s spatial analogical reasoning skills, and so the role that language (whether signed or spoken) plays in the development of these skills is not clear. For example, Zwiebel and Mertens (1985) found that the figural analogical reasoning subtest of a nonverbal intelligence battery did not load significantly on any factor in a factor analysis in a group of deaf children aged between 10 and 12 years. In a group of hearing children of the same age, this subtest loaded very heavily on one of the two factors that were identified. The authors interpret this as indication that the deaf children have a “weak or absent thinking component” (p. 29; although this component did appear to emerge in an older group of deaf children, aged 13–15 years). This suggests that the deaf children may follow a normal trajectory in terms of their development of analogical reasoning, that is, this cognitive skill is delayed rather than deviant in its acquisition. Sharpe (1985) also found differences between signing deaf children’s and hearing children’s figural analogical reasoning skills, which were poorer in the former group.

Although the findings of poor verbal analogical reasoning in the context of poor oral or signed language are not surprising, the relationship between language and spatial analogical reasoning needs to be further examined. It could be argued that all analogical reasoning tasks, regardless of their content (verbal or nonverbal/spatial), require a high level of language skills through the use of self-talk or inner speech. A study of adults with unilateral brain lesions showed that participants with left hemisphere lesions were impaired on both verbal and spatial analogical reasoning, supporting the role of the left hemisphere and language in spatial reasoning (Langdon & Warrington, 2000). Equally, it is theoretically possible that spatial analogical reasoning tasks rely minimally on language skills, if it is assumed that such problems can be solved without describing or verbally labeling the relations

between the items. Thus, the influence of language on spatial analogical reasoning is unclear and may not be equivalent to its influence on verbal analogical reasoning.

The current study aimed to compare both verbal and spatial analogical reasoning skills in hearing children and deaf children, the majority of whom used spoken language. It is hypothesized that children's scores on the verbal analogy subtest of the verbal and spatial reasoning test for children (VESPARCH; Mellanby & Langdon, 2010) will differ between groups, with hearing children outperforming deaf children. It is also hypothesized that, within each of the groups, children's verbal analogical reasoning skills will be predicted by their language ability, as measured through tests of vocabulary and receptive grammar. In terms of spatial analogical reasoning skills, given previous empirical inconsistencies, no specific hypotheses are proposed; however, spatial analogy performance serves as a surrogate measure of general cognitive competence, which at face value has less language dependence (than the verbal analogy task).

Methods

Design

The study employed a between-groups design comparing deaf children and hearing children. All children completed measures of language and analogical reasoning on one occasion.

Participants

The participants in this study are the same sample as for a previously published study (Figueras, Edwards, & Langdon, 2008). However, for clarity, information regarding the sample is reproduced here. Sixty-nine children aged between 8 and 12 years were assessed: 22 deaf children with cochlear implants (mean age = 9.8 years, $SD = 1.6$), 25 deaf children who used conventional hearing aids (mean age = 10.8 years, $SD = 1.5$), and 22 hearing children (mean age = 10.2 years, $SD = 1.3$). Children were recruited through the Cochlear Implant Programme in a London teaching hospital and through schools within southern England. To

reduce between-group variability, children from both groups were recruited from the same schools. The mean length of implant use was 6.4 years ($SD = 2.0$). Children with learning disabilities or significant developmental delays (as identified by local educational services or on the basis of testing by the implant team clinical psychologist) were excluded. Children in the deaf group were born to hearing parents and were prelingually deafened (hearing loss either congenital or acquired before 2.5 years of age). For details of etiology of deafness, see Figueras and colleagues (2008).

The deaf children had a sensorineural loss in the moderate (41–70 dB), severe (71–95 dB), or profound (95+ dB) ranges. Figueras and colleagues (2008) provide data on the number of children within each of these categories (there are seven missing data points for the group of deaf children), and the mean and SD of hearing loss levels for the two deaf groups. The hearing loss figures represent the unaided pure-tone-average threshold in dB hearing loss in the better ear, taken from the most recent available audiograms, averaged over the frequencies of 500, 1,000, 2,000, and 4,000 Hz. Neither hearing loss nor age of cochlear implantation/initiation of hearing aid use was significantly related to any of the cognitive or language tests (Spearman's correlations with age partialled out).

Seventy percent of the deaf children were orally educated; the remaining children used Total Communication (a combination of spoken English and key British Sign Language [BSL] signs, using English rather than BSL grammatical structures), with the exception of one child with hearing aids who predominantly used BSL. All children were able to understand simple, orally presented test instructions. The groups were matched on age, gender, socioeconomic status, and ethnicity (see Figueras et al., 2008).

Measures

Measures of verbal and spatial reasoning. The verbal and spatial analogical reasoning tests are part of the VESPARCH test battery (Mellanby & Langdon, 2010) designed for 9 to 13-year olds that was developed from Langdon and Warrington's (1995) verbal and spatial reasoning test for adults. There are 25 questions in each of the test sections, presented in multiple-choice

formats, where the child has to select one from four possible responses. Administration instructions are short and simple, and for each subtest, there are five practice items in which feedback on the child's performance is provided, to help clarify the task demands. The multiple-choice format of the VESPARCH allows for pointing, a nonverbal response. In addition, the test places minimal load on participants' memory because the problem and response alternatives are available for each test item until the child has made his or her response (Langdon & Warrington, 1995, 2000). Data on the VESPARCH are available for more than 2,000 hearing children aged 9–12 years. The test has not been used previously with deaf children, but was chosen because of its presentation and response formats, and because there is no standardized, validated alternative that has equivalent verbal and spatial forms. The internal consistency is adequate (Cronbach's alpha 0.7) and test-retest at 1 year correlates significantly ($r = 0.6$).

The VESPARCH consists of problems of category (identifying the item that does not belong to the category to which the other items belong) and analogy (recognizing relationships between items), within both the verbal and spatial domains. In light of this study's hypotheses, only the analogical reasoning subtests of the VESPARCH were administered.

Verbal analogy. Each of the 25 items on the VESPARCH verbal analogical subtest comprises a pair of words that bear a relation to each other (opposites, cause-effect, part-whole, etc.), followed by a single word and four alternative words with which the single word can be paired. Participants are asked to select one of the four alternatives so that it relates to the single word in the same way as the first pair of words relate to each other. For example, a verbal analogy problem is of the type "boat is to sea, as car is to sky, wall, road or roof."

The vocabulary in the verbal subtests is a selection of frequent words appearing in books for 9-year-old children. As the VESPARCH progresses and the logic of test items becomes more complex, the demands on the children's level of vocabulary remain constant (Langdon & Warrington, 2000). Although the words used in the test should be familiar to most children in

the current sample, it remains a possibility that younger children (and particularly those who are deaf) would have difficulty with some of the test items not because of genuine reasoning difficulties, but as a result of poor vocabulary skills. Children in the current study were thus told that, if they did not know the meaning of a word, they could ask the experimenter. When requested, the same word definitions were given to each participant.

Spatial analogy. The VESPARCH spatial analogy subtest is equivalent to the above, with the exception that words are substituted by abstract geometrical shapes, most of which cannot be verbally encoded. The visual-spatial demands of the test are minimized through the selection of simple shapes that do not rely on fine perceptual discrimination skills (Langdon & Warrington, 1995, 2000). The relations between the shapes include transformation (e.g., square to circle, oblong to ellipse) and rotation.

Measures of language.

The British Picture Vocabulary Scale, Long Form. The British Picture Vocabulary Scale, Long Form (BPVS, Dunn, Dunn, Whetton, & Pintilie, 1982) measures receptive vocabulary. Children are presented with four pictures on a page and are instructed to point to the one corresponding to the word given by the examiner. Because hearing loss may interfere with the accuracy with which some words are heard, all participants in the current study were asked to repeat each word prior to pointing to a response. When children did not correctly perceive a given word, it was repeated for them, making lip reading as clear as possible.

The Test for Reception of Grammar—Version 2. The Test for Reception of Grammar—Version 2 (TROG-2, Bishop, 2003) is a measure of receptive grammar. It consists of 80 items with a multiple-choice format: each item contains four pictures, one of which corresponds to the short sentence spoken by the examiner, whereas the rest are lexical and/or grammatical foils. To illustrate, "The ball is not only small but blue" is an example of the grammatical construct "not only x, but also y," and "The mouse is chased by the elephant" is a "reversible passive" construct (in reversible

passive constructions, the subject can be exchanged with the agent in the by-phrase and still leave a correct logical sentence, although with the opposite meaning).

Procedure

All relevant ethical permissions were obtained from the participating institutions. Written parental consent and oral assent from the children were obtained prior to data collection. The measures for this study were administered in the same testing session as those reported in Figueras and colleagues (2008), the total time for administration being approximately 90 min. Tests were always administered in the same order so that potential effects of order of test presentation would be constant across groups. Care was taken to give test instructions with maximum clarity, making sure that all children could clearly see the tester's lip movements and that their attention was appropriately focused. The same instructions were given to children in each of the three groups, including nonverbal gestures and facial expressions (e.g., pointing or raised eyebrows to indicate a response was expected).

Statistical Analysis Procedure

The deaf children with cochlear implants and the deaf children with conventional hearing aids were collapsed into one group following initial analyses that found no differences between them on the language measures. The reasoning and language variables were normally distributed for the resultant group of deaf children as well as the group of hearing children. Performance on each of the language and reasoning tests was compared across the two groups (*t* tests with Bonnferroni correction). Fixed-order regression analyses were performed to explore the relationships between language and reasoning variables.

Item-by-item analysis of the TROG-2 test was carried out by calculating the proportion of children that passed each block. When a child failed at five consecutive blocks, the test was discontinued for that child (see TROG-2 manual, Bishop, 2003). The calculation of the proportion passing that block was based on reduced total number of children.

Results

Reasoning Tests

The total number of correct responses was calculated for each child on the verbal and spatial VESPARCH tests (maximum possible score of 25 for each test). It is of interest to note that, although the VESPARCH test had not previously been used with 8-year olds, the three 8-year olds in the hearing group all scored well within the measurement scale of the test (actual scores achieved were 13, 15, and 16 out of 25 on verbal VESPARCH). The scores on verbal VESPARCH were markedly lower in the deaf group than in the hearing group. The spatial VESPARCH scores were also significantly lower in the deaf group although the difference was less marked and became nonsignificant with Bonnferroni correction. These findings are presented in Table 1. Particularly noteworthy is that when the difference between spatial and verbal scores was calculated for each group (spatial score minus verbal score), the resulting mean was near zero for the hearing children, indicating little difference in verbal and spatial reasoning abilities in this group. However, the spatial scores of the deaf children were significantly higher than their verbal scores.

Language Tests

The standardized scores in the hearing group for grammar (TROG-2) and vocabulary (BPVS) were approximately average (i.e., close to 100). The standardized

Table 1 Comparison of VESPARCH scores of deaf and hearing children (*t* tests)

Reasoning test	Deaf children, <i>N</i> = 47	Hearing children, <i>N</i> = 22	<i>t</i>	<i>p</i>
	Mean (<i>SD</i>)	Mean (<i>SD</i>)		
Verbal VESPARCH	10.40 (5.01)	16.36 (3.59)	-5.58	<.005
Spatial VESPARCH	14.28 (4.45)	16.45 (3.20)	-2.05	=.045
Spatial minus verbal VESPARCH	3.98 (3.76)	0.09 (2.72)	3.89	<.005

Note. VESPARCH, verbal and spatial reasoning test for children.

Table 2 Comparison of age-standardized language test scores of deaf and hearing children (*t* tests)

Language test	Deaf children, <i>N</i> = 47 Mean (<i>SD</i>)	Hearing children, <i>N</i> = 22 Mean (<i>SD</i>)	<i>t</i>	<i>p</i>
TROG-2	68.55 (16.3)	100.68 (8.5)	-10.75	<0.001
BPVS	64.49 (17.7)	98.14 (13.0)	-8.80	<0.001

Note. TROG-2, Test for Reception of Grammar—Version 2; BPVS, The British Picture Vocabulary Scale, Long Form.

scores of the deaf children, however, were more than two *SDs* lower ($p < .001$ in both cases). These results are presented in Table 2. The proportion of the deaf children who passed each of blocks A–F of the TROG-2 (i.e., scoring 4 out of 4 correct) was almost as high as for the hearing children. After Block F, the pass rate was considerably lower for the deaf children. Blocks H, I, and L particularly difficult—even more so than some of the succeeding blocks (for the percentage pass rates for each block and the grammatical construct being tested, see Table 3).

Two fixed-order regressions were performed, one on the deaf group and one on the hearing group, with

Table 3 Percentage of children passing each of the TROG-2 blocks

Grammatical construct	% Of deaf children passing block	% Of hearing children passing block
A. Two elements	100	100
B. Negative	100	100
C. Reversible in and on	100	100
D. Three elements	87	100
E. Reversible subject-verb-object	83	100
F. Four elements	77	96
G. Relative clause in subject	47	96
H. Not only <i>x</i> but also <i>y</i>	13	73
I. Reversible above and below	23	91
J. Comparative/absolute	66	96
K. Reversible passive	30	77
L. Zero anaphor	13	68
M. Pronoun gender/number	43	86
N. Pronoun binding	17	82
O. Neither–nor	15	82
P. <i>x</i> but not <i>y</i>	21	77
Q. Postmodified subject	21	86
R. Singular/plural inflection	13	77
S. Relative clause in object	9	32
T. Centre-embedded sentence	0	0

Note. TROG-2, Test for Reception of Grammar—Version 2.

age, spatial VESPARCH, and TROG-2 or BPVS entered in that order as regressors of verbal VESPARCH. Spatial VESPARCH was used as a surrogate for general cognitive competence and entered into the regression in order to examine differences in reasoning performance that were specific to language and not just due to differences in general cognitive competence.

In the deaf group, TROG-2 or BPVS accounted for a significant additional amount of variance in verbal VESPARCH scores after entering age and spatial VESPARCH—for TROG-2, $R^2 = .26$, $F(1,41) = 44.315$, $p < .0005$; for BPVS, R^2 change = .24, $F(1,41) = 36.14$, $p < .0005$. However, in the hearing group, the language measures did not account for any additional variance after controlling for age and spatial VESPARCH. The full details of these analyses are presented in Table 4.

Two further pairs of hierarchical regressions were performed on the study sample as a whole ($N = 69$), one pair predicting verbal VESPARCH scores, the other predicting spatial VESPARCH scores. Hearing status (deaf versus hearing), age, and either TROG-2 or BPVS were entered in that order as predictors.

When predicting verbal VESPARCH, hearing status, age, and either TROG-2 or BPVS each contributed significant amounts of variance, totaling approximately 70% in both cases. In these two analyses, hearing status accounted for approximately 26% of the variance, and the language measures accounted for an additional 25% of variance, after hearing status and age were accounted for.

In contrast, when predicting spatial VESPARCH, hearing status accounted for only around 5% of the variance (although this did just reach statistical significance). Here, the language measures again predicted a significant amount of variance after that accounted for by hearing status and age together (around 10%

Table 4 Fixed-order multiple regression with age, spatial VESPARCH, and TROG-2 or BPVS entered in that order as regressors of verbal VESPARCH

Group	Independent variables	R^2 change	F change	df	p	Final model β	p for β
Hearing	Age	.27	7.34	1,20	.013	.331	.052
	Spatial VESPARCH	.30	13.03	1,19	.002	.571	.002
Deaf	Age	.26	15.16	1,43	<.0005	.197	.041
	Spatial VESPARCH	.24	19.69	1,42	<.0005	.338	.002
	TROG-2	.26	44.32	1,41	<.0005	.565	<.0005
	Or BPVS	.24	36.14	1,41	<.0005	.567	<.0005

Note. VESPARCH, verbal and spatial reasoning test for children; TROG-2, Test for Reception of Grammar–Version 2; BPVS, The British Picture Vocabulary Scale, Long Form.

for both the TROG-2 and BPVS), but notably less than that for the verbal VESPARCH. The total amount of variance in spatial VESPARCH accounted for by these two models was approximately 40%. The full details of these analyses are presented in Table 5.

Discussion

In this study, deaf children performed more poorly than hearing children on tests of vocabulary and grammar; there was no difference in the performance of the deaf children in relation to whether they used conventional hearing aids or a cochlear implant. The most probable explanation for this latter finding is that, despite the efforts made, it was not possible to match the two deaf groups on a number of key variables. The deaf children with hearing aids had milder hearing losses, had been fitted with their hearing device at a younger age, and had used their hearing aids for longer, than the children with cochlear implants. Although the implanted children had probably used conventional hearing aids for a period of time before

receiving the implant, they presumably would have been unable to receive sufficient gain from them to access speech sounds, hence the need for a cochlear implant.

In this study, consistent with the findings of Bandurski and Galkowski (2004), the deaf children scored substantially lower than the hearing children on verbal analogical reasoning. Furthermore, verbal reasoning was markedly poorer than spatial reasoning for the deaf children, but not for the hearing children. In contrast, our findings did not support those of either Sharpe (1985) or Zwiebel and Mertens (1985): the results of our study did not indicate poorer spatial analogical reasoning skills in the deaf children or suggest that an “abstract thinking component” to intelligence is absent in deaf children before about 12 years of age. Although the deaf children in Sharpe’s sample used signing as their primary mode of communication, they were born to hearing parents and therefore differences in language proficiency may have accounted for her findings.

The deaf children also scored substantially lower than the hearing children on the task assessing

Table 5 Fixed-order multiple regressions with hearing status (deaf vs. hearing), age, and TROG-2 or BPVS entered in that order as regressors of verbal and spatial VESPARCH

Reasoning task	Independent variables	R^2 change	F change	df	p	Final model β	p for β
Verbal VESPARCH	Hearing status	.28	24.86	1,65	.000	.526	.000
	Age	.19	22.66	1,64	.000	.436	.000
	TROG-2	.26	60.22	1,63	.000	.726	.000
	Or BPVS	.23	57.68	1,63	.000	.710	.000
Spatial VESPARCH	Hearing status	.06	4.19	1,66	.045	.244	.045
	Age	.26	24.33	1,65	.000	.507	.000
	TROG-2	.10	11.30	1,64	.001	.457	.001
	Or BPVS	.11	11.70	1,64	.001	.468	.001

Note. VESPARCH, verbal and spatial reasoning test for children; TROG-2, Test for Reception of Grammar–Version 2; BPVS, The British Picture Vocabulary Scale, Long Form.

understanding of grammar (TROG-2, Bishop, 2003) and on the British Picture Vocabulary Scale (BPVS, Dunn et al., 1992), whereas scoring similarly on spatial analogy. Within each of these two groups of children (deaf and hearing), the age-standardized scores on the two language tests were similar (i.e., their vocabulary and grammar skills were at a similar level). In our regression models, the language measures (TROG-2 and BPVS) contributed substantial additional variance in verbal VESPARCH in deaf children (after controlling for age and general cognitive competence), but did not in hearing children. In addition, vocabulary or grammar skills accounted for substantially more variance in verbal analogical reasoning compared with spatial analogical reasoning, after taking into account the child's hearing status and age. Thus, it seems likely that verbal reasoning is considerably more adversely affected than spatial reasoning in those deaf children with poor language proficiency. If language is also used in solving spatial analogies within this group, it plays a more minor role.

Closer examination of the deaf children's responses in the grammar test supports the contention that the problem with verbal analogical reasoning is related to a more general problem in understanding complex language structures. The deaf children performed similarly to the hearing children on the simple items early in the test, including ones with negatives and those with four elements (e.g., "The horse sees the cup and the book"); however, their performance fell dramatically once relative clauses, reversible structures, and relational structures (such as neither-nor, and x but not y) were encountered. The performance of the deaf children closely resembled that of younger hearing children aged 5–6 years, who also have particular difficulty with blocks H, I, and L (E. Svirko, unpublished data). This finding supports the view that deaf children's acquisition of grammar is not "deviant" but merely delayed (Bishop, 1983). Our recent work reporting deficits in deaf children on tests of executive function that were related to poor language skills also supports the more general role of language level in cognitive function in deaf children (Figueras et al., 2008).

It would be particularly informative to ascertain whether the same pattern of results as reported

here is found when deaf children who are native signers complete these verbal and spatial reasoning tests in order to unpack further the relationship between language and reasoning.

The present study has a number of limitations. We cannot exclude the possibility of biased sampling, given the small groups and their recruitment from a tertiary referral center. The study did not evaluate spoken language which may have accounted for additional variance. There was no systematic check that the deaf children accurately heard the spoken instructions, although the investigator made every effort to ensure that this was the case. Although the majority of deaf children were orally educated and all had speaking parents, there was nevertheless some heterogeneity of language modality experience in the group of deaf children. In addition, level of hearing loss was only available for 40 out of the 47 deaf children, and so could not be fully taken into account in the statistical analysis. A final limitation of the study is that the relation of scores on formal analogical reasoning tests to competence in everyday life was not explored and is therefore unclear.

The difficulties deaf children encounter in developing verbal analogical reasoning skills have educational implications. As Goswami (2001) notes, analogical reasoning is a powerful logical tool for explaining and learning about the world, contributing to the acquisition and restructuring of knowledge. Children who show developmental delays in this ability are at risk of underachieving in many areas of their learning and educational attainment. Our results suggest that, given the relation of language to verbal analogical reasoning skills, improving support for language development, in particular in terms of the vocabulary and grammatical structures used to describe relationships between concepts, might be expected to facilitate improvement in analogical reasoning skills for deaf children. Encouraging children to externalize their inner speech while solving problems may help their educators to identify the specific gaps in their language knowledge that are impeding their development of cognitive skills such as analogical reasoning. These possibilities remain to be confirmed by further research.

Note

1. The term “deaf children” refers both to those who are deaf and those who are hard of hearing throughout this article.

Conflicts of Interest

No conflicts of interest were reported.

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