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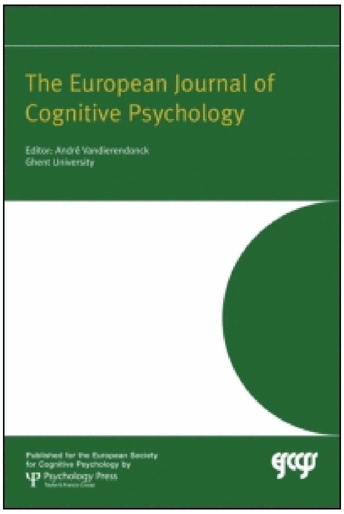

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Editorial

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Intellectual functioning of deaf adults and children: Answers and questions

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Intelligence has long been seen as linked to the spoken and written word. Because most deaf people have poor spoken language skills and find reading a significant challenge, there is a history in both psychology and education of considering deaf individuals to be less intelligent or less cognitively flexible than hearing individuals. With progress in understanding natural signed languages and cognitive abilities of individuals who lack spoken language, this perspective has changed. We now recognise, for example, that deaf people have some advantages in visuospatial ability relative to hearing people, and there is a link between the use of natural signed languages and enhanced visuospatial abilities in several domains. Such findings contrast with results found in memory, where the modality of mental representation, experience, and organisation of knowledge lead to differences in performance between deaf and hearing individuals, usually in favour of the latter. Such findings demonstrate that hearing loss and use of a natural sign language can influence intellectual abilities, including many tapped by standardised IQ tests. These findings raise interesting questions about the place of spoken language in our understanding of intelligence and ways in which we can use basic research for applied purposes.

Understanding intellectual functioning in special populations is a difficult undertaking—or should be. That is, there is a natural tendency for individuals in majority populations to view those in minority or special populations as varying quantitatively from the norm (indicated by means or standard deviations) rather

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than qualitatively. Anthropologists and sociologists have learned the dangers of such ethnocentric interpretations of data, and yet in psychology it seems that the lesson may still be in need of teaching.

One place where such instruction is readily available is in efforts to understand and describe intellectual functioning of deaf individuals, both those who are children of deaf parents (less than 5% of all deaf individuals; Mitchell & Karchmer, 2004) and deaf children of hearing parents raised with sign language rather than spoken language. This is not a new endeavour and, indeed, many early nonverbal intelligence tests originally were constructed specifically for the purpose of being able to test deaf as well as hearing individuals (e.g., Binet & Simon, 1909; Pintner & Patterson, 1916, 1917). Yet even while developing instruments that do not depend on language, such enquiries never resolved the questions of the extent to which intelligence depends on language and how it might differ qualitatively or quantitatively with the use of spoken versus other forms of language. In this regard, research involving deaf individuals can be most informative.

This paper seeks to highlight some of the apparent answers to questions concerning the cognitive abilities of deaf individuals as demonstrated via standard psychological paradigms. More importantly, it will point up the variety of remaining questions concerning interactions of language and cognition and the ways in which our formal and informal views of intelligence are influenced by our emphasis on spoken language—appropriately or not. Throughout most of this discussion, *intellectual functioning* rather than *intelligence* will be used for reasons that go beyond psychological accuracy, and bear on some of the cultural and historical issues that make this such a difficult area of investigation and an even more difficult area in which to obtain consensus. This review thus has three primary goals. One of these is to provide a critical analysis of the possible role(s) of spoken language as a necessary condition for intellectual functioning, together with potential implications for perspectives on deaf individuals. As a corollary, the paper also will consider the view that signed languages and spoken languages are fully comparable in their support of intellectual functioning. In order to understand both the history of these two perspectives and the ways in which they have guided both research involving individuals and the education of deaf children, it is essential to recognise that it was only in 1960 that the first study revealed American Sign Language (ASL) to be a ‘‘true’’ language rather than a gestural system (Stokoe, 1960/2005). Therefore, what had previously been considered an issue of ‘‘thinking without language’’ (Furth, 1966), is now seen as a question of how spoken and signed language may differentially affect cognitive functioning (Marschark, 2003). The paper thus offers a historical sketch of research on deafness, language, and intelligence, followed by consideration of several specific areas of relevant research, and then implications for future research and practice.

WHAT WE CAN LEARN FROM HISTORICAL STUDIES OF DEAFNESS, LANGUAGE, AND INTELLIGENCE

Historical descriptions of deaf individuals and their communities (e.g., Groce, 1985; Lang, 2003; Woll & Ladd, 2003) provide us with some understanding of their social and linguistic functioning, including some notion of how they and their signed languages were viewed by others as effective means of both communication and learning. In Plato's *Cratylus* (360 BC), for example, Socrates poses the question ''Suppose that we had no voice or tongue and wanted to indicate objects to one another. Should we not, like the deaf and dumb, make signs with the hands, head, and the rest of the body?'' In the fourth century AD, Saint Augustine, wrote in *De Quantitate Animae* and *De Magistro* about deaf people's use of gestures and signs in discussing learning of the Gospel. He asked: ''Have you never noticed how men converse, as it were, with deaf people by gestures and how the deaf themselves in turn use gestures to ask and answer questions, to teach and to make known either all their wishes or, at least, a good many of them?''

If Plato and St. Augustine saw deaf people as educational examples, Sultans of the Ottoman Court saw them as a valuable resource, as deaf people lived at court and taught sign language to those who were not permitted to speak in front of the Sultan (Woll & Ladd, 2003). In the late seventeenth century, one of the best known historical examples of a signing deaf community was established in America. A large deaf population had emigrated from a deaf community in Kent, England, and after settling in Scituate and other New England towns, eventually gathered at Martha's Vineyard (Massachusetts) (Groce, 1985). There, intermarriage led to an extremely high rate of deafness and sign language was a natural and accepted form of communication.

Together with early reports from philosophers, physicians, and scientists, such descriptions provide a better understanding of deaf people and sign language throughout history. From the Venerable Bede's history of the English people, *The Ecclesiastical History of the English Nation*, written around 700 AD, to William Harvey's 1636 observations (when he was not working on the human circulatory system) of deaf siblings signing to each other, there were questions about how the lack of spoken language and/or the presence of sign language might affect knowledge and thinking (Marschark, Lang, & Albertini, 2002, chap. 2). Clearly, at least some signing and nonsigning deaf people were accepted members of both the community and scientific circles, and there was a variety of internationally prominent deaf individuals who were artists and scientists, like Sir John Gaudy, a signing deaf artist knighted in Britain in the late seventeenth century (Evelyn, 1955); and his contemporaries French Academy member Guillaume Amontons, recognised as a pioneer in optical telegraphy and for laying the foundation for the study of temperature, and Leo Lesquereux, a paleobiologist who was the first member of the (US) National Academy of Sciences (Lang & Meath-Lang, 1995).

By the late 1800s, scientific observations of deaf children were undertaken to better understand ‘‘the deaf-mute language’’ (which actually differed in each country) and its relation to higher mental functioning. Sign language was being used in schools for the deaf in France, the Netherlands, and the United States at a time when psychology was struggling to decipher the relations of language, images, and thought (Marschark & Spencer, 2006). On one side were commentators like Bartlett (1850), who argued that ‘‘an intelligent person … entirely destitute of all knowledge of language [is] an impossibility’’ (p. 86). Preyer (1882) took up a similar position, arguing that deaf children may understand a variety of complex concepts and abstractions of a lower order, but that without speech could not have many more of higher order abstractions ‘‘than very intelligent animals’’.

Such notions had been dismissed as early as the 1600s by investigators who had observed the behaviour of signing deaf adults (Stokoe, 1960/2005), and careful observations and analyses of deaf individuals by investigators like William James (1893), demonstrated that although higher mental processes might often be accompanied by spoken language, they did not require it. Nevertheless, the belief that normal cognitive development depends on the acquisition of spoken language persisted in many places through to the end of the twentieth century (see Spencer & Marschark, 2006, for reviews).

INTELLIGENCE, IQ, AND DEAF CHILDREN

The spoken language–sign language controversy has not gone away. Following more than 100 years of spoken language dominance in deaf education (led early on by Alexander Graham Bell, e.g., 1898/2005); however, recognition that signed languages were ‘‘true’’ languages, beginning in the 1960s (Stokoe, 1960/2005), led to their scientific study and their renewed use in educational settings. Importantly, today as 100 years ago, most deaf children have hearing parents who generally lack good sign skills or other means to effectively communicate with them. In the absence of access to early communication and language despite intensive ‘‘oral’’ training, most deaf children thus enter school with language delays of up to 2 years, and these lags often become greater with age (Geers, 2006). To early investigators who observed such delays (e.g., Pintner & Patterson, 1916, 1917), it often appeared that the lack of *spoken* language was the cause of academic and intellectual challenges—not that it was the failure to acquire appropriate language skills in any mode that created barriers to deaf children’s learning. Indeed, there was ample evidence then (see Lang, 2003) and there is now (see Marschark et al., 2002) that natural signed languages (like American Sign Language [ASL], Italian Sign Language [LIS], and British Sign Language [BSL]) can provide deaf children with normal developmental trajectories and academic achievement. Yet, only about 25% of deaf children develop intelligible speech (Beattie, 2006; Cole & Paterson, 1984), and specific difficulties with spoken language—and with speech-dependent literacy skills (Traxler, 2000) led to considerable difficulty in assessing deaf children's intellectual functioning using traditional tests and measurements.

One difficulty in this regard is the lack of sign language translations of intelligence and achievement tests. About 1 in 1000 infants in Western countries is born with a severe to profound hearing loss ($\geq$ 60 dB in the better ear), and the (US) National Center for Health Statistics (NCHS) reported over 965,000 children between 3 and 17 years of age with some degree of hearing loss, with more than 210,000 of them classified as deaf (NCHS, 1999). Cone-Wesson (2003) noted that this is ''an exceptionally high prevalence for a potentially disabling condition''. However, it is still not high enough to justify test publishers creating sign language versions of most IQ tests, and ad hoc translations used in several studies have not yet been validated. Thus, while deaf children tend to score below hearing children by about 1 standard deviation on verbal intelligence scales even when the effects of language skill are controlled (Braden, 1994; Braden, Kostrubala, & Reed, 1994), it is unclear whether those tests are inappropriate for deaf individuals or whether hearing loss necessarily affects verbal intelligence independent of language fluencies.

Lacking consensus on the above issue, most investigators currently make use of nonverbal, performance IQ tests with deaf children (e.g., Vernon, 1967, 1968/2005; see Maller, 2003, for a review). But even with performance tests, it is unclear how the language and cognitive disadvantages experienced by most deaf children in early childhood affect test validity. In a still influential review article, Vernon (1968/2005) reported that deaf and hard-of-hearing individuals had essentially the same distribution of nonverbal intelligence as the general population and only deaf children with other disabilities tended to score lower than hearing peers. More recently, studies involving deaf children have found nonverbal IQ to vary widely as a function of both the tests involved and the greater heterogeneity of deaf children relative to hearing children (Marschark, 1993b). Maller (2003, pp. 452–453) provided one review of such studies in which deaf children were reported to obtain IQ scores comparable to hearing peers on the Kaufman Assessment Battery for Children (K-ABC), but lower scores than hearing peers on the Leiter International Performance Scale–Revised (LIPS-R), the Comprehensive Test of Nonverbal Intelligence (CTONI), and the Universal Nonverbal Intelligence Test (UNIT).

Differences between deaf and hearing children on both verbal and nonverbal intelligence tests traditionally have been interpreted in terms of delayed cognitive development due to impoverished early language environments and reduced early stimulation or a direct consequence of separate, nonstandard education (Pintner & Patterson, 1917; Raviv, Sharan, & Strauss, 1973). During the 1950s and 1960s, when maternal rubella epidemics resulted in large numbers of deaf children, tests specifically designed for deaf children were popular (see Blennerhassett, 2000, for a review). Such tests are now outdated and no longer used, although some investigators argue that special norms are necessary so that deaf children can be compared only to other deaf children (Vernon & Andrews, 1990). This view may appeal to some notions of equality, but the position has been shown to be psychometrically and conceptually invalid (Braden, 2001; Jensen, 1980).

More recently, it has been argued that both assessment tools and teaching methods designed for hearing children may not match the cognitive abilities and knowledge of deaf children (Marschark & Lukomski, 2001; Zweibel, 1987). This situation may argue for the inappropriateness of particular tests, but it also may be that the general findings are valid with respect to deaf children's cognitive abilities relative to hearing age-mates, indicating the need for a greater understanding of educational practice at home and at school. Indeed, variability is so great among deaf children, that assessment involving only a single cognitive test may well misrepresent an individual child's abilities (Marschark, 1993b, chap. 7; Pizzuto, Ardito, Caselli, & Volterra, 2001; Rönnberg, 2003). Consideration of intelligence among deaf individuals also is complicated by the fact approximately 30–40% of them have some other syndromic or non-syndromic condition that might affect test performance or related prior learning (Cone-Wesson, 2003). The variability contributed by such conditions could be partially responsible for any apparent overall, quantitative differences between deaf and hearing samples or qualitative differences in the configuration of abilities within the deaf population (Braden, 1994; Marschark, 1993b, chaps. 7–9; Ulissi, Brice, & Gibbins, 1990). Alternatively, it has been suggested that deafness, and especially hereditary deafness, might confer some intellectual advantages.

Kusché, Greenberg, and Garfield (1983), for example, examined nonverbal intelligence and verbal achievement in four groups of deaf high school students, conforming to a 2 (deaf or hearing parents) × 2 (genetic or nongenetic deafness) design and found that students with genetic deafness had higher mean scores (112 according to WISC-R and WAIS norms) than their matched groups with nongenetic deafness (101 and 102 on the WISC-R and WAIS, respectively). Because only one of two genetically deaf groups had hearing parents, Kusché et al. ruled out early language stimulation and quality of parental communication as possible loci of the IQ differences and suggested ''natural, cultural, and/or historical selection'' (p. 464) instead, a conclusion also reached by Zweibel (1987) in a study of Israeli children. More recently, Akamatsu, Musselman, and Zweibel (2000) found in a Canadian longitudinal study that IQs of deaf school children with nonsyndromic, hereditary deafness were equal to or higher than those of hearing peers.

Typically, however, differences in cognitive performance between deaf and hearing children, favouring the latter group, emerge as the gap between their linguistic and academic competencies increases, especially with regard to literacy skills. It thus may be that the intellectual development of deaf children is impeded by their relatively poor reading and writing skills (Traxler, 2000), a suggestion consistent with the positive relation found between the verbal scales of the WISC and literacy measures in deaf children (e.g., Geers & Moog, 1989; Moores & Sweet, 1990). Alternatively, the link between print literacy and intelligence might be viewed as creating qualitative rather than quantitative differences between deaf and hearing children. In this view, deaf children may gain much less from reading than hearing peers, and thus become more reliant on perceptually based reasoning rather than the abstract reasoning that is promoted by print literacy (Zweibel & Mertens, 1985), an orientation that could affect their performance in a variety of other cognitive domains (Marschark, 2005; McEvoy, Marschark, & Nelson, 1999).

LANGUAGE, EXPERIENCE, AND COGNITION IN DEAF ADULTS AND CHILDREN

Given the environments in which most deaf children grow up, it is not surprising that they are cognitively and intellectually more heterogeneous than hearing peers. Antia, Stinson, and Gaustad (2002) argued that as a result of their early environments, deaf children are likely to encounter ''unfamiliar situations'' more frequently than hearing peers and thus may have a greater need for precisely those problem-solving skills they lack. The issue of familiarity of task environments and the extent to which they elicit knowledge and strategies in deaf children's repertoires has arisen not only in cognitive tasks that demand explicit problem-solving strategies (e.g., Furth, 1966; Marschark & Everhart, 1999) but also in tasks that implicitly tap similar knowledge and skills (memory, associative learning, reading, etc.). In short, it appears that both growing up deaf and growing up with language skills 2–4 years behind those of hearing peers (Geers, 2006) has both general and specific effects on cognition. Some differences observed between deaf and hearing individuals now are understood to be related to sign language use rather than hearing loss *per se*. Other differences appear directly linked to a relative lack of auditory experience or a relative dependence on visual experience.

Language fluency and memory

Links between language and memory in deaf individuals have been of particular interest to psychological investigators for more than 100 years and, aside from literacy, memory has been the single most studied aspect of psychological functioning in deaf children (see Marschark, 1993b, chaps. 8 and 9). At a general level, Marschark (1993a) suggested that language fluency and, in turn, social interaction during childhood could have an influence on the structure and contents of semantic memory and other cognitive skills (e.g., working memory), even into adulthood. He argued that children with better communication skills would be more likely to have interactions with others from whom memory strategies and memory-relevant content knowledge can be learned, either explicitly or implicitly, and those children also are more likely to have interactions with diverse individuals with whom remembering things might be important. In all of these respects, Marschark argued that sign language and spoken language were fully comparable, given interactions with adults who possess fluent language skills.

At a more specific level, in contrast, a variety of investigators have argued that memory in deaf children is closely linked to their spoken language skill and, not coincidentally perhaps, inversely linked to their degree of hearing loss (e.g., Conrad, 1970, 1979). We have long known, for example, that hearing adults and children have longer memory spans than deaf individuals, and that those deaf individuals who use spoken language have longer spans than those who use sign language (Mayberry & Eichen, 1991; Pintner & Patterson, 1917). However, the consistent finding that deaf individuals tend to demonstrate equal forwards and backwards memory spans (e.g., Wilson, Bettger, Niculae, & Klima, 1997)—contrasting with the usual finding from hearing individuals that backwards span is significantly more difficult—signals the fact that there are qualitative as well as quantitative differences to be considered.

Studies conducted over the past decade have now demonstrated a connection between spoken language skill and linguistic working memory in deaf individuals. Using a variety of paradigms involving, for example, oral versus manual articulatory suppression and words that sound or are signed similarly, investigators have shown that deaf individuals may make use of either speech-based or sign-based codes in working memory (Lichtenstein, 1998; MacSweeney, Campbell, & Donlan, 1996; Marschark & Mayer, 1998; Wilson & Emmorey, 1997). Because individual signs take longer to articulate than individual words, however, speech skill generally is found to be positively related to working memory capacity in deaf individuals. Lichtenstein (1998), for example, demonstrated positive relations between working memory, speech, and reading among deaf college students; and Marschark and Mayer (1998) reported both a positive relation between working memory and speech skill and a negative relation between working memory and sign skill (where skill was presumed to reflect relative reliance on one language or the other).

Language skills aside, deaf students are rarely as efficient in their memory strategies as hearing peers and typically show significantly lower serial recall across a wide range of stimulus materials regardless of their preferred language modality (Krakow & Hanson, 1985; Lichtenstein, 1998; Logan, Mayberry, & Fletcher, 1996; O'Connor & Hermelin, 1973). Although this difference may be in part a consequence of the greater demands on cognitive capacity of either sign-based coding (greater memory demands) or speech-based coding (lesser fluency) relative to hearing peers, there are other cognitive differences that may reflect more generalised divergence in intellectual processing by deaf and hearing individuals.

Strategic and content differences in memory and cognition

The finding of both qualitative and quantitative differences in memory, as well as other differences in basic cognitive functioning between deaf and hearing individuals has been a source of considerable controversy in the field of deafness (see Marschark, 2003; Moores, 2001) in large part because claims of *differences* have often been taken as claims of *deficiencies*. There now appear to be data which directly indicate that language fluencies of deaf individuals can have positive as well as negative consequences for various cognitive processes. Courtin (1997), for example, suggested that the morphological structure of sign language might provide deaf children with a cognitive advantage with regard to concept formation. His reasoning followed from the fact that in French Sign Language (Langue des Signes Français, LSF), as in other sign languages, signs below the *basic* level (e.g., ''tree'') often do not exist (e.g., ''maple'', ''oak''). In order to specify a maple tree in ASL, for example, one would first sign TREE and then fingerspell ''maple''. Courtin noted that basic-level, ''generic'' signs in LSF often have iconic or metonymic characteristics. Accordingly, he suggested that a generic sign sometimes refers to the prototypical element of the category, having a representative shape of exemplars in the category. But generic signs also refer to the intentional properties of the category in that they encompass some of the characteristic properties (e.g., the trunk and branches). Courtin therefore argued that categorisation might be easier for a deaf child who is a native user of LSF than for a hearing child.

Courtin (1997) conducted an experiment involving hearing children of hearing parents and deaf children of deaf parents, all aged 5–6 years, who were shown pictures sharing either a superordinate category and a generic, to-be-instantiated sign (e.g., a cake and a strawberry tart) or a ''schematic'' conceptual relation (e.g., a pudding and a dessert spoon, both related to desserts). He found that the deaf children were more likely to match pictures on the basis of categorical choices than schematic choices, whereas the reverse was true for hearing children (cf. Marschark, Convertino, McEvoy, & Masteller, 2004). Deaf children did not show greater overall categorisation abilities that hearing peers, but the underlying commonality in sign concepts clearly facilitated their application of a categorical strategy (cf. Marschark & Everhart, 1999). Courtin did not evaluate children of hearing parents who were acquiring sign language, but recent findings involving college students who were already skilled in sign language have indicated no difference in the frequency with which deaf and hearing students provide superordinate responses in a single-word free association task (Marschark et al., 2004).

If such results suggest interactions of language and concept learning in deaf children, there was already abundant evidence for qualitative differences in conceptual organisation in semantic memory between deaf and hearing individuals. Studies of semantic memory organisation during the 1970s—usually attempts to explain observed quantitative differences in recall—typically revealed considerable overlap in deaf and hearing students' associative knowledge, and concluded that there was little if any difference in memory organisation (e.g., Hoemann, Andrews, & DeRosa, 1974; Koh, Vernon, & Bailey, 1971; Liben, 1979). More recently, studies have revealed significant differences in the strength and spread of associations among concepts that seem likely to affect functioning in a variety of cognitive and academic domains (e.g., Marschark et al., 2004; McEvoy et al., 1999).

McEvoy et al. (1999), for example, examined the organisation of conceptual knowledge in deaf and hearing college students using a single-word association task. They found high overlap in primary associates for the two groups ($r = .77$), but significant differences on several dimensions indicated that hearing students had greater coherence and consistency in conceptual organisation relative to deaf students. Marschark et al. (2004) obtained similar results using category names and category exemplars as stimuli. Deaf and hearing students again showed high overlap in their associative responses, as they produced the same primary associates for 82% of the stimuli. Contrary to their predictions, Marschark et al. found that deaf students were significantly less likely than hearing peers to respond to a category name with an exemplar, even while the two groups were equally likely to respond to an exemplar with a category name. This result indicates asymmetric category-exemplar relations in semantic memory for deaf but not hearing students (see also Liben, 1979).What evidence is available therefore suggests that despite considerable similarity in the knowledge organisation of deaf and hearing individuals, there are consistent differences that can influence intellectual functioning. Still unclear, however, is the locus of results indicating differences in cognitive organisation. Marschark, Convertino, and LaRock (in press) have argued that such findings reflect both developmental and educational factors, rather than being a consequence of hearing loss *per se*. Indeed, there are several general differences in information processing between deaf and hearing individuals that appear to reflect very different orientations to learning, memory, and cognition. One of these relates to an emphasis on relational versus individual item information.

Deaf learners and relational processing

Ottem (1980) was the first to point out a difference between deaf and hearing individuals in their relational versus individual-item information processing, in his review of over 50 studies of concept learning, conservation, classification, memory, and problem solving. He observed that when tasks had involved only a single dimension (e.g., size or number), deaf individuals usually performed comparably to hearing age-mates. However, when tasks required simultaneous consideration of two or more dimensions (e.g., size and shape), the performance of hearing adults and children usually surpassed that of deaf peers. Such findings reflect differing orientations towards relational versus individual-item processing, a dimension known to affect performance in a variety of cognitive tasks. In a study exploring deaf children's memory for text, for example, Banks, Gray, and Fyfe (1990) found that deaf and hearing children recalled equal amounts of text, but deaf children's recall tended to be composed of disjointed parts rather than whole idea units. Similar findings were obtained by Marschark, De Beni, Polazzo, and Cornoldi (1993) in a study in which deaf and hearing students were matched either for age or reading ability and read reading-level appropriate passages. Overall, the deaf adolescents recalled significantly less than their hearing age-mates, but more than the younger reading-matched children. When recall was scored for the number of relational units or individual words recalled, deaf students were found to remember proportionately fewer relations than words, while the reverse was true for both groups of hearing students. Consistent with the Banks et al. findings, these results were interpreted as indicating that deaf students tend to focus on the meanings of individual words or pieces of text rather than taking a more relational, holistic approach to reading (see Wilhelm & Oberauer, 2006 this issue).

The finding that deaf individuals tend not to automatically apply relational processing strategies also may help to explain the consistent finding of poorer serial recall for word, sign, and picture stimuli relative to hearing age-mates. The lack of strong associative bonds in semantic memory may result in less relational processing in both episodic memory (e.g., list learning) and reading, where deaf students are seen to adopt more word-by-word strategies and typically fail to make either text-connecting or gap-filling inferences even when they have the linguistic and world knowledge necessary to do so (Strassman, 1997). Indeed, the lack of an integrative orientation may be at the root of deaf students' performance below hearing age-mates on a variety of memory, problem solving, and academic tasks.

From this perspective, the findings with regard to spoken language and tasks involving temporal or sequential information may be seen as indicating that deaf individuals have alternative ways of coding and remembering information rather than any generalised cognitive deficits. Unfortunately, some of those alternatives may not be as appropriate or successful as the codes and strategies employed by hearing individuals in academic and other settings, but deaf individuals may have advantages in domains that take advantage of their greater reliance on visuospatial information.[1] Either as one component of higher order cognitive processing, or in and of itself, this point of divergence in deaf and hearing individuals may help to clarify our understanding of intellectual processes in deaf adults and children. It therefore will be worthwhile studying their visuospatial functioning in more detail.

VISUOSPATIAL COGNITION IN DEAF INDIVIDUALS: HEARING LOSS OR SIGN LANGUAGE USE?

The arguments of Akamatsu et al. (2000), Zweibel (1987), and others suggesting hereditary advantages in IQ for deaf individuals, as well as those suggesting alternative information processing strategies, indicate that a full understanding of the intellectual functioning of deaf adults and children must include attention to cultural, environmental, and neuropsychological contributions to development. Beyond interactions of language development, cognitive development, and heredity, early experience clearly has impact on the development of the nervous system and organisation within the brain which, in turn, will influence learning in some subtle and not so subtle ways. Although it is still unclear whether the observed neuropsychological (Corina, 1998; Emmorey, 2001; Rönnberg, 2003) and behavioural (Marschark et al., in press) differences observed in the laboratory have any functional effects in real-world activities, several such differences have been identified that appear to influence and reflect differences in intellectual functioning.

Todman and Cowdy (1993) and Todman and Seedhouse (1994), for example, found that profoundly deaf children, aged 6–16 years, surpassed hearing peers on the Compound Stimulus Visual Information (CSVI) task. The CSVI test requires short-term memory of complex visual figures and subsequent performance of actions based on different dimensions of the figures. The only case in which the performance of hearing children exceeded that of deaf children is when the task involved serial presentation of parts of a stimulus and serial (ordered) recall. Belmont, Karchmer, and Bourg (1983), however, warned that the heterogeneity in deaf children's early experiences would likely affect coding strategies and preferences. They presented 16 deaf and 16 hearing 11-year-olds with computer-generated stimulus arrays differing in spatial and temporal order; the children then recalled the digits or were asked to choose the presented sequences from a pair of alternatives. Belmont et al. found that all the hearing children adopted temporal coding strategies, whereas nine deaf children adopted spatial coding strategies and seven adopted temporal strategies. After

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[1] In fact, the majority of deaf individuals do have some residual hearing, but there have been few attempts to discern the extent to which their technologically aided or unaided hearing influences performance in either cognitive tasks or academic settings.

determining children's coding preferences, Belmont et al. used a task that required children to switch to the alternate, spatial or temporal, strategy. The switch reduced performance by both deaf and hearing children, but only hearing children showed a recovery of performance after several trials.

Unfortunately, the Belmont et al. (1983) study did not distinguish between children who relied on sign language versus spoken language, a dimension now recognised as influencing visuospatial performance in several domains. On average, for example, deaf adults and children have been found to surpass hearing individuals in visuospatial such as mental rotation (Emmorey, Kosslyn, & Bellugi, 1993), face recognition (Bellugi et al., 1990), mental image generation (Emmorey & Kosslyn, 1996), detecting motion (Neville et al., 1997), and sign language (Swisher, 1993) in peripheral vision, and redirecting visual attention from one location to another (Corina, Kritchevsky, & Bellugi, 1992; Rettenback, Diller, & Sireteanu, 1999). However, some of those advantages are now recognised to be due to the use of a natural, visuospatial sign language rather than a function of hearing loss. Emmorey and Kosslyn (1996) and Emmorey et al. (1993), for example, found that both deaf and hearing signers were faster in generating complex (but not simple) mental images than nonsigning peers; and in a two-dimensional rotation task, Emmorey et al. found deaf and hearing signers to have faster response times than hearing nonsigners.[2] Chamberlain and Mayberry (1994) further demonstrated that deaf individuals who relied on spoken language did not differ from hearing nonsigners on the mental rotation task, while Talbot and Haude (1993) showed that level of sign language expertise (but not age of acquisition) affected mental rotation performance with three-dimensional block figures.

Bettger, Emmorey, McCullough, and Bellugi (1997) hypothesised that the experience of people who use ASL in discriminating facial expressions that have linguistic interpretations also might enhance their ability to discriminate among faces. In three experiments involving adults, they demonstrated a significant advantage supporting their prediction. Importantly, however, only those aspects of face processing related to ASL grammar and lipreading enhanced performance, and there was no general enhancement of visual discrimination (e.g., for inverted faces). Bettger et al. also examined the perceptual abilities of 6- to 9-year-old deaf children with deaf or hearing parents. These ''early signers'' and ''late signers'' were compared to a group of hearing children with hearing parents using the Benton Faces Test, a task in which a model photograph of a face must be compared to other photographs which may be of the same or different people (seen from the front, in profile, or in shadow). Bettger et al. found that deaf

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[2] The difference observed by Emmorey et al. (1993) was apparently due to deaf people being faster in making judgements about normal versus mirror-image orientation, rather than in rotation speed *per se*.

children with deaf parents consistently scored significantly higher than either the hearing children or the deaf children with hearing parents, who did not differ significantly from each other. These results indicate that individuals who are native signers develop face-specific perceptual abilities, reflecting a specific link between language and visuospatial abilities (McCullough & Emmorey, 1997).

Although other visuospatial abilities still appear to be a function of hearing loss rather than sign skill (e.g., sensitivity to motion in peripheral vision), results of this sort emphasise that interactions of hearing loss, language, and experience must be considered if we are to fully understand the intellectual abilities of deaf children and adults. Even if there are few, if any, generalised advantages for deaf individuals by virtue of hearing losses alone, better understanding of those domains in which they differ from hearing peers in qualitative and quantitative ways—including domains in which sign language confers some advantage—may offer insights into methods for improving deaf children's academic learning, thus bridging research and practice.

CONCLUSIONS AND IMPLICATIONS

For those interested in intelligence and the relations of verbal and nonverbal processes, deaf individuals have always presented a puzzling case. When nonverbal, performance intelligence tests are used, deaf and hearing individuals generally perform similarly. Verbal intelligence tests developed for hearing individuals may not be appropriate for use with deaf individuals, but not only because of the language barrier involved. To the extent that deaf children have different patterns of early socialisation and diversity of experiences from hearing peers, as well as exposure to variable quality in academic instruction, standardised verbal intelligence tests may not be ''culture fair''. What then are we to make of the fact that deaf adults and children may employ fundamentally different coding strategies than hearing peers—due either to hearing loss or their reliance on signed languages? In cases where their performance falls below that of hearing peers, many educators and investigators suggest that the tests appropriately indicate a lack of ''normal'' cognitive-academic skills (e.g., Luetke-Stahlman & Luckner, 1991; Sharpe, 1985; see also, Cornoldi, 2006 this issue). Yet there have been few attempts to demonstrate superior performance by deaf individuals in domains where they appear to have cognitive advantages.

It is not surprising that children growing up without hearing or with diminished hearing are more dependent of visual information than normally hearing peers, and it thus should not be surprising if there are neurological and neuropsychological correlates of such differences early in development. What is surprising is how little we make use of those findings in either theorising about intellectual functioning of deaf individuals or in seeking to meet demonstrated needs in their academic performance. In the educational sphere, Detterman and Thompson (1997, p. 1083) argued that ''lack of understanding of the cognitive skills underlying educational interventions is the fundamental problem in the development of special education. Without understanding the full complexity of cognitive abilities, special educational methods can never be special.'' With regard to intelligence and intellectual functioning, however, reliance on spoken language and performance comparable to hearing children often is still considered the ''gold standard''. Admittedly, this situation is largely a consequence of parental wishes that their deaf child appear as ''normal'' as possible, but more than 150 years of research concerning language, cognition, and intellectual functioning among deaf individuals—and an equal period of trying to make them speak, read, and perform academically like their hearing siblings—should be enough to tell us that this is unlikely to occur.

The fact that deaf individuals both have a greater reliance on visual information than hearing peers and have to deal with visual and verbal (also via the visual modality) information consecutively rather than simultaneously (e.g., in naming and explanations of ongoing events) clearly will result in their having different perceptual and cognitive strategies than those who can draw on both visual and auditory input. Furthermore, most deaf children are raised in environments in which their parents cannot effectively communicate with them and in which there is a mandate for education in a system that is designed for hearing children. Such environments would not be particularly sensitive to the special needs of visuospatial learners. Yet, little attention has been given to how deaf individuals come to accommodate this situation and often succeed despite the barriers placed before them.

Attempts over the years to alter the landscape for deaf children by requiring intensive oral-only education or placing them in regular local classrooms have done little to improve literacy and other academic skills or to make deaf children look more like hearing children (Traxler, 2000). Perhaps it is time to follow Detterman and Thompson's (1997) suggestion that we need to better understand the normal intellectual functioning of deaf children in order to adapt our instructional methods to match their strengths and needs. This seems a far better use of psychological research than gratuitously attempting to make deaf children adopt the learning behaviours of hearing children (some years delayed). We already have many of the answers; it seems that our problem lies in finding the right questions.

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