Auditory-visual Perception of Speech in Children with Learning Disabilities: The McGurk Effect

Perception auditivo-visuel de la parole chez les enfants ayant des troubles d'apprentissage : l'effet McGurk

Carol Boliek
Connie Keintz
Linda Norrix
John Obrzut

Abstract

This study addressed whether or not children with learning disabilities (LD) are able to integrate auditory and visual information for speech perception. The effects of vision on speech perception can be demonstrated in a stimulus mismatch situation where unconnected auditory and visual inputs are fused into a new percept that has not been presented to either modality and represents a combination of both (McGurk Effect). It was of interest to determine if the McGurk effect was present in children with LD. Twenty children with LD and 20 normal controls, matched for sex and age, participated in this study. Participants represented a younger (6-9 years of age) and an older (10-12 years of age) group. Ten adult controls (20-40 years of age) also served as participants. Control participants demonstrated that inter-modal integration became stronger with development and experience. The response patterns of the children with LD indicated that whereas these children have some ability to integrate audio-visual speech stimuli, audio-visual speech perception did not become stronger with experience and development.

Abrégé

Cette étude visait à répondre à la question suivante : dans la perception de la parole, un enfant ayant des troubles d'apprentissage peut-il intégrer simultanément l'information auditive et visuelle? Les effets de la vision sur la perception de la parole peuvent être démontrés lors d'une situation de disparité des stimuli, où des données auditives et visuelles sans lien entre elles sont fusionnées dans une nouvelle image mentale n'ayant pas été présentée dans l'un ou l'autre des modes et représente une combinaison des deux (effet McGurk). Il était intéressant de déterminer si l'effet McGurk était présent chez les enfants atteints de troubles d'apprentissage. Vingt enfants ayant des troubles d'apprentissage et 20 enfants témoins, jumelés selon l'âge et le sexe, ont participé à l'étude. Ils ont été divisés en deux groupes d'âge : 6 à 9 ans et 10 à 12 ans. Dix adultes témoins (20 à 40 ans) ont aussi participé à l'étude. Les participants témoins ont démontré que l'intégration multimodale devenait plus importante avec le développement et l'expérience. Les schémas de réponses des enfants ayant des troubles d'apprentissage ont révélé que même si ces enfants ont une certaine capacité à intégrer les stimuli auditivo-visuel, la perception de la parole auditivo-visuelle n'augmentait pas avec le développement et l'expérience.

Key words: McGurk effect, learning disability, speech perception

Carol Boliek, PhD
Department of Speech and Pathology and Audiology,
University of Alberta
Edmonton, Alberta

Connie Keintz, PhD
Florida Atlantic University
Boca Raton, Florida USA

Linda Norrix, PhD
University of Arizona
Tucson, Arizona USA

John Obrzut, PhD
University of Arizona
Tucson, Arizona USA

Studies using uni- and cross-modal tasks have shown that children and adults with learning disabilities (LD) exhibit deficits in basic auditory perception, attention and memory that might in part, be responsible for deficits observed in more complex cognitive processing (Boliek, Obrzut, & Shaw, 1988; Obrzut, Horgesheimer, & Boliek, 1999; Molfese, 2000; Molfese, 1989; Plante, Boliek, Mahendra, Story, & Glaspey, 2001). Deficits in phoneme awareness, visual perception and auditory-visual perception also have been implicated in children and adults with LD (e.g. Plante, Van Petten & Senkfor, 2000).

Mann and Liberman (1984) tested kindergarten children on a series of verbal short-term memory tasks such as repetition of word strings. Verbal short-term memory positively correlated with early reading ability. Moreover, phoneme awareness in kindergarten predicted between 30 to 40 per cent of variance in first grade reading abilities (Mann, 1993). Based on the reading, spelling and general language skill levels found in their longitudinal sample of young children, Mann and Liberman (1984) concluded that good or poor language skills are related to good or poor reading skills, respectively. Additional evidence indicates that poor readers have a general processing deficit related to speech perception (Godfrey, Syrdal-Lasky, Millay, & Knox, 1981), and to the ability to segment speech appropriately (Morais, Cluytens, & Alegria, 1984). However, others (see Hulslander, et al., 2004) have shown that performance on sensory processing and reading tasks can be predicted by IQ scores in children with reading disabilities. Morais et al. (1984) found no differences between children with learning disorders and their matched counterparts on tasks requiring reproduction of tones. Some non-language tasks do not discriminate between children with and without LD but non-language tasks requiring visual processing, complex auditory sequencing and higher attention and memory demands clearly distinguish the two groups (Obrzut, Conrad, & Boliek, 1989; Plante, et al., 2001). Therefore, phonological deficits and auditory processing difficulties alone may not account for developmental learning disabilities (Plante et al., 2001).

Visual perception in children with LD has been studied using a variety of language and non-language paradigms. "Low-level" visual processes like visual masking, eye movement, saccadic suppression and spatial-temporal integration are important for higher-level information processing tasks (Breitmeyer & Ganz, 1976). Data from studies using non-language, visual persistence paradigms with school-aged children demonstrated that children with LD do not perform as well as typically developing children (Slaghuis, Lovegrove, & Davidson, 1993; Slaghuis & Ryan, 1999). Moreover, visual processing deficits seem to be present even in older children and adolescents with LD (Slaghuis, Twell, & Kingston, 1996).

Taken together, the body of literature to date indicates that children with LD have basic uni- and cross-modality processing difficulties for material that is presented to the auditory, visual, or both sensory systems, whether the material is language or non-language in content. During face-to-face interactions, speech perception requires the integration of the auditory and visual signals at some point in the process. Early integration of acoustic and optic signals may occur prior to phonetic evaluation (Summerfield, 1992). Alternatively, later integration would imply that phonetic features of acoustic and optic signals are evaluated separately and then integrated (Massaro, 1987).

Although speech perception has primarily been considered an auditory process, recent studies have shown that visual information provided by a talker's mouth and face strongly influence what an observer perceives (Green, 1998; Green, Kuhl, Meltzoff, & Stevens, 1991; Massaro, 1987; McGurk & MacDonald, 1976; Rosenblum & Saldana, 1996). The effects of vision on speech perception are particularly clearly illustrated by a stimulus mismatch situation where the separate auditory and visual inputs are fused into a new percept that has not been presented to either modality and arises from a combination of both (McGurk Effect). By studying how perceptual systems deal with inter-modal discrepancies, it is possible to gain information about the multisensory organization that underlies speech perception. Studies using the McGurk paradigm have demonstrated that the effect is present in very young children (Burnham, 1998; Rosenblum, Schmuckler, & Johnson, 1997) but becomes stronger with typical development and experience (Massaro, 1984; Massaro, Thompson, Barron, & Laren, 1986).

Only a few studies using multisensory paradigms have included children with communication disorders (Hayes, Tiippana, Nicol, Sams, & Kraus, 2003; Obrzut, 1979). De Gelder, Vroomen, and van der Heide (1991) found that children with autism were relatively good at lip reading but when audio and visual stimuli were presented together, children with autism relied less on the visual signal when compared to typically developing peers. In another study, De Gelder and Vroomen (1998) found that poor readers had poor categorical perception with regards to phoneme boundaries, and their responses were more variable than age-matched or reading-matched controls. They also showed that children with poorer reading skills did less well on lip reading tasks. The data suggested a trend that children with dyslexia were less influenced by vision than controls. This conclusion was derived statistically from comparing responses from an auditory-only to a visual-only condition versus an inter-modal task. In contrast, Hayes and colleagues (Hayes et al., 2003) found that children with LD did less well than control counterparts on an incongruent audiovisual task and reported the visual component of the task more often than a blend of the auditory and visual stimuli. It is not clear from these preliminary studies whether children with LD have difficulties in the early stages of integration or after the auditory and visual signal are combined. Hayes et al. (2003) showed preliminary evidence that perhaps for a subgroup of children with LD, processing breaks down at the level of the brainstem prior to sensory integration (Hayes et al., 2003). The authors also suggest that auditory-

Table 1
Average age and standard scores[1] (standard deviation) for control and LD groups.

	Younger LD	Younger Control	Older LD	Older Control
Average age	8 yrs 6 mos (16.35 mos)	7 yrs 9 mos (9.02 mos)	11 yrs 9 mos (5.97 mos)	11 yrs 3 mos (6.33 mos)
Reading*	76.0 (9.35)	116.5 (13.72)	87.6 (10.03)	109.8 (16.13)
Math*	92.3 (17.71)	111.3 (13.59)	85.7 (12.15)	107.8 (12.60)
Verbal IQ	92.2 (15.10)		89.4 (4.96)	
Performance IQ	100 (12.99)		94.8 (10.35)	
Full Scale IQ	95.6 (12.32)		91.2 (6.21)	

[1] Standard IQ and achievement tests scaled to a mean of 100 with a standard deviation of 15. Verbal, Performance and Full Scale IQ measures were derived from the WISC-III. Reading and Math scores were derived from standardized either individual (Broad Reading and Math scores derived from the Woodcock Johnson Tests of Achievement) or group (Iowa Tests of Basic Skills) administered achievement batteries.
* significant group (LD vs. Control) difference at p < .05

visual integration may be affected by cognitive load and of the individually variable compensatory strategies used by children with LD.

The tasks used to date typically involved abstract relationships among various uni- and cross-modal stimuli. This raises the question of whether children with LD would show similar deficits involving inter-modal stimuli that are more ecologically valid (i.e., human speech). Specifically, it was of interest to examine speech perception in children with LD. This study was designed to address whether or not children with LD are able to integrate auditory and visual information for speech perception. A secondary, exploratory question was whether or not the skill was related to development and/or experience. Further, it was of interest to compare these indices of multisensory organization in children with LD to those of typically achieving children.

Method

Participants

The participants were 20 children with LD and 20 normal controls, matched for sex and age. All children were native English speakers from monolingual English speaking homes. Both LD and control participants were selected to represent a younger (6-9 years of age) and an older (10-12 years of age) group. Each age group, therefore, was comprised of 10 participants with LD and 10 control children. For the purpose of comparison and cognitive-linguistic end points, 10 control adults (20-40 years of age) also served as participants. All participants had normal vision and hearing based on results from an audiometric screening (at least 20dB HTL, each ear) and visual screening tests conducted by the school nurse. Children with corrected hearing or vision were not included in the study. The children with LD were recruited from the public school system where they were diagnosed by a multidisciplinary team based on standardized tests [typically the Wechsler Intelligence Scale for Children III (WISC III; Wechsler, 1991)and the Woodcock Johnson Tests of Achievement, (Woodcock, McGrew, & Mather, 1989) and classroom performance, including responses to modified teaching-learning approaches inclusive of the diagnostic protocol. Each participant with LD was selected on the basis of his or her abilities and achievement profiles to represent primary deficits in the auditory-linguistic domain. All children with LD were being treated for a language impairment by a speech-language pathologist and received individualized instruction by a special educator for reading deficits. Children with LD were excluded from the study if: (a) there was a documented co-morbidity of Attention Deficit Hyperactivity Disorder (ADHD), (b) the full-scale IQ scores were below a standard score of 80 points, (c) processing deficits were primarily visual-spatial in nature as documented in the diagnostic report and (d) the child was also being treated for a motor speech deficit. The age matched control participants were selected from the same public school system based on average to above average standardized achievement scores (Iowa Tests of Basic Skills; Hoover, Dunbar & Frisbie, 2001) and teacher report of at least average performance in the classroom. Average age and standardized test scores are shown in Table 1. Significant differences ($p < .05$) were found for reading and math, between participants with learning disabilities and age-matched controls. We did not obtain individual IQ scores for control participants as a part of this study. Instead, we inferred average cognitive skills in this group of typical learners from the educational performance criteria.

Materials

Visual stimuli were prepared by videotaping a female talker while producing several instances of the syllables /bi/ and /gi/. From these recordings, two syllables were selected consisting of a single token of /bi/ and /gi/. The auditory stimuli consisted of the syllables /bi/ and /gi/

spoken by a female and a male speaker. The speakers were recorded while producing several repetitions of each of the syllables in a soundproof room. The syllables were digitized and analyzed. For each speaker, a single /bi/ and /gi/ with similar durations, which closely matched the durations of the corresponding video tokens, were selected for the experiment.

Two types of auditory-visual stimuli were created. The first included auditory and visual signals from the female face and voice (congruent stimuli). The second stimuli were created by cross-dubbing the visual and auditory information such that the female face was paired with the male voice (incongruent). For both congruent and incongruent stimuli, all possible pairings of the auditory and visual /bi/ and /gi/ were created, resulting in four auditory-visual stimuli. Two of the four auditory-visual stimuli provided conflicting phonetic information (i.e., auditory /bi/ paired with visual /gi/). This is a stimulus for which participants typically report perceiving a /di/ or /θi/ syllable thus creating a new percept that integrates information from both auditory and visual modalities. These percepts are referred to as a "fusion" response. The second conflicting auditory-visual stimulus paired auditory /gi/ with visual /bi/. This situation typically produces a percept of /bgi/, which reflects a combination of the phonetic information presented to both modalities and is referred to as a "combination" response. The combination response involves a less ambiguous bi-labial (/bi/) visual signal, which is characterized by opening of the lips prior to the articulation of the auditory velar /gi/ consonant, leading to the combined percept of /bgi/. The final two auditory-visual stimuli served as control tokens because they provided matched phonetic information (auditory /bi/ paired with visual /bi/ and auditory /gi/ paired with visual /gi/). A block of trials consisted of 10 repetitions of the set of four auditory-visual stimuli in random order for a total of 40 trials of congruent and 40 trials of incongruent presentations. In addition to the pretest practice trials, eight practice trials consisting of two repetitions of each of the four stimuli were created at the start of each block of 40 trials.

Stimuli were presented on a video monitor with two loudspeakers. The audio signal was presented with a peak intensity of 65 dB SPL for the vowel at the approximate location of the subject's head. The participants were instructed to watch and listen to each trial and report what was said by the speaker. A total of six possible responses was presented to the participants in print form prior to the practice trials. These options included /bi/, /gi/, /di/, /vi/, /θi/, and /bgi/. After each trial, participants immediately responded verbally to the experimenter who recorded the response. Cues to watch and listen were repeated throughout the blocks of trials. Trials were presented only when the participant's eye gaze was focused on the monitor and head orientation was at body midline.

All children were given practice trials until they fully understood the task. No participant included in the study performed at chance or below on the practice trials employed. All children were able to accurately identify practice stimuli (8 trials) presented in the *auditory-only* mode (100 per cent accuracy) and *visual-only* mode (98 per cent accuracy) with both male and female stimulus samples. No differences on performance accuracy between participant groups were found for any of the practice trials. In addition, all children included in the study were assessed for their ability to combine percepts that resulted from the McGurk effect during the practice trials, and for their ability to report these percepts verbally. Finally, the experimenter was blind to the participants' status at the time of testing. The experimenter who conducted the practice trials was different from the examiner who conducted the actual test trials.

Results

Individual responses to fusion and combination tokens were averaged within each participant group. A score of 10 indicated that there were no fusion or combination responses and conversely, a score of 0 represented a fusion or combination response, each time a McGurk token was presented. Therefore, the lower the auditory response (lower scores), the stronger the McGurk effect. Note that production of anything other than a /bi/ would indicate a fusion response (i.e., /di/ or /θi/) or a visual capture (i.e., /gi/). Table 2 shows the means and standard deviations for all groups and stimuli. A nested design, 2 Group (control, LD) X 3 Age (younger, older, adult) series of one-way analysis of variances were conducted for each stimulus type (congruent, incongruent) and for combination and fusion responses separately.

There were no group or age differences for combination responses (e.g., /bigi/) on either congruent or incongruent stimuli, $F\ (4, 45) = 1.46$, $p = .2287$; $F\ (4, 45) = 0.87$, $p = .4871$, respectively. However, group differences were found for fusion responses for congruent and incongruent stimuli, $F\ (4, 45) = 3.96$, $p < .0078$; $F\ (4,45) = 2.98$, $p < .0288$, respectively. Tukey pairwise comparisons (group X age, n=10 for each stimulus type) and contrasts (younger, older LD, younger controls vs. older controls and adults; n=2 for each stimulus type) revealed that younger LD, older LD and younger controls differed from older controls and adults for fusion responses to both congruent and incongruent stimuli ($p<.0005$ and $p < .0023$, respectively; *Bonferroni* criteria of $p < .004$). Younger LD, older LD and younger controls did not differ from each other on fusion responses for either congruent or incongruent stimuli. No statistical differences between older controls and adults were found for fusion responses for either congruent or incongruent stimuli.

To further examine whether these findings were related to development and experience, exploratory "Pearson product moment" correlations were calculated for each participant group's tasks responses and achievement (reading and math) scores. Additional correlations between tasks responses, verbal, performance and full-scale IQ

Table 2
Means and (standard deviations) of fusion and combination responses for all participant groups and stimulus type. Note: The lower the number the stronger the McGurk Effect.

Participant Group	Congruent Stimuli Fusion Responses	Incongruent Stilmuli Fusion Responses	Congruent Stimuli Combination Responses	Incongruent Stimuli Combination Responses
LD Younger	5.60 (4.43)	3.60 (4.27)	8.80 (2.78)	7.70 (3.77)
LD Older	4.80 (4.69)	2.60 (3.34)	6.30 (4.03)	6.50 (3.60)
Control Younger	7.20 (3.97)	2.10 (3.11)	6.30 (4.35)	5.70 (4.60)
Control Older	1.70 (3.65)	0.20 (0.42)	6.20 (4.39)	6.00 (4.22)
Control Adults	1.40 (3.10)	0.10 (0.32)	4.70 (3.47)	4.40 (4.06)

Table 3
Correlations among participant groups, achievement scores, IQ scores and McGurk task responses. Low scores on the McGurk task indicated increased strength of the effect, so negative correlations should be interpreted inversely

Task	Reading	Math	Verbal IQ	Performance IQ	Full-scale IQ
Young Learning Disabled Group					
Fusion Congruent	.21	.21	.22	.02	.14
Fusion Incongruent	.22	-.46*	.23	.29	.29
Combination Congruent	-.63**	-.23	-.01	.06	.02
Combination Incongruent	-.56*	.004	-.13	.16	.00
Older Learning Disabled Group					
Fusion Congruent	-.56*	-.58*	-.02	-.53*	-.46*
Fusion Incongruent	-.18	-.33	-.16	-.57*	-.55*
Combination Congruent	-.33*	-.19	-.03	-.43*	-.37
Combination Incongruent	-.44*	-.29	-.07	-.50*	-.45*
Young Control Group					
Fusion Congruent	.58*	.27			
Fusion Incongruent	-.14	.13			
Combination Congruent	.26	.71**			
Combination Incongruent	.15	.39			
Older Control Group					
Fusion Congruent	.18	.29			
Fusion Incongruent	-.10	.08			
Combination Congruent	.09	.32			
Combination Incongruent	.08	.02			

Note- * $p< .05$, ** $p<.01$

scores were calculated for both LD participant groups. The correlations are shown in Table 3. Based on the exploratory nature of this analysis, statistical correction for multiple correlations was not applied. Because low scores on the McGurk task indicated increased strength of the effect, negative correlations should be interpreted inversely. For example, a negative correlation between Combination Congruent and Reading means that the weaker the McGurk effect, the lower the reading achievement score.

The patterns of significant correlations between achievement scores and McGurk responses varied by age and group. In the children with LD, a weaker McGurk effect on one or more of the stimulus sets was correlated with lower reading or math performance, or both. In the younger control children, a stronger McGurk effect on two of the stimulus sets was correlated with higher reading and math performance scores. No significant correlations between achievement and McGurk responses were found for the older control group. Only the performance IQ and full-scale IQ scores were significantly correlated with McGurk responses in the older group of children with LD. In this older LD group, weaker McGurk effects were correlated with lower performance and full-scale IQ scores.

Discussion

In the current study, a series of audio-visual stimuli designed to elicit a McGurk effect was presented to younger and older groups of children diagnosed with a learning disability and age-matched typically developing children. A group of healthy adults also participated in this study to indicate the endpoints of cognitive and language development. McGurk effects were recorded if the audio-visual stimuli resulted in either a fusion (creation of a new percept that integrates information from both auditory and visual modalities) or a combination response (creation of a new percept that combines the phonetic information presented to both modalities). On average, participants reported similar numbers of combined /bgi/ responses. This was not surprising based on previous studies (Green, 1998; Green et al., 1991). The combined response can be explained in terms of a less ambiguous bilabial (/bi/) visual signal, which is characterized by opening of the lips prior to the articulation of the auditory velar /gi/ consonant, leading to the combined percept of /bgi/. The fusion data revealed that both younger and older groups of children with LD and control participants demonstrated a McGurk effect. The integration of the auditory and visual signals was significantly stronger in the older control participants and did not differ significantly from the strength of the effect demonstrated by the adult participants. This is consistent with the findings by Massaro, et al. (1986) who used similar age groups of 4 to 6-year-olds and 6 to 10-year-olds and argued that inter-modal integration becomes stronger with development and experience. The response patterns of the children with LD indicated that these children have some ability to integrate audio-visual speech stimuli, but that the effect is weak and does not change with development. The strongest evidence comes from the older group of children with LD who demonstrated an effect similar to that of both the younger children with LD and their matched controls. This finding can be interpreted in the context of an audio-visual association impairment. The weaker McGurk effect for children with LD also may be due to: (a) poorly stored representations of visual-auditory associations, (b) lack of intersensory corticocortical connections of association areas, (c) a lack of experience in predicting a speech percept, (d) attention issues in modality selection, or (e) some combination of some or all of these factors.

Evidence from infant studies has shown that by age 6 months, babies understand the correspondence between visual and auditory phonetic signals (Kuhl & Meltzoff, 1982; 1984). It is not clear whether neural substrates involved in multisensory integration are specific to audio-visual speech perception or if multisensory functions can be handled by different cortical sites. We argue that the McGurk effect demonstrated by the young children in the current study reflects this early understanding of auditory-visual correspondence. We believe that this achieved through "generic" multisensory integration neural mechanisms (like that found in infants), as opposed to a rule-governed link to a cognitive percept of speech. This study's most revealing finding was in the performance of the older group of children with LD. We reasoned that multisensory integration specific to audio-visual speech perception would become stronger with experience and development, as suggested by Massaro et al. (1986). An increase of fusion responses was evident in the older control children. However, the number of fusion responses from the older children with LD did not increase from the number of responses given by both groups of younger children. It appears that the older children with LD in this study did not demonstrate developmental change based on a life experience with the integration of visual gestures and auditory signals. We speculate that the older children with LD may not be able to benefit from experience because of poor phonetic segmental awareness, as suggested in previous studies (De Gelder & Vroomen, 1998). Speech perception is thought to rely on a system of stored representations characterized by distinctive features of motor commands and acoustic interpretations (Liberman & Mattingly, 1985; Stevens, 2002). These learned visual-auditory associations enhance the prediction of a speech percept (Massaro, 1984; Massaro, Thompson, Barron, & Laren, 1986; Welch & Warren, 1980). The results of this study indicate that children with LD either have acquired an incomplete set of stored representations, or have difficulty accessing the visual-auditory associations to make good predictions of a speech percept, or both.

The processing of auditory-visual speech involves temporal integration and reconciliation of the trajectory of the visible articulators leading up to the acoustic event. Munhall, Gribble, Sacco and Ward (1996) suggest that successful synchronization of the visual and acoustic signal occurs if articulatory movement and acoustic signals are not more than 250 ms apart. All of the auditory-visual speech stimuli in this study were well below this mark (approximately 20 to 30 ms apart). Perhaps children with LD have difficulty perceptually integrating simultaneous acoustic signals with ambiguous articulatory movements, as required in the fusion stimulus conditions, but are able to synchronize when the articulation is more salient (i.e., bilabial /bi/) in the conditions containing combination stimuli.

It has been shown that the role of attention to a particular input, such as attention to auditory stimuli over visual stimuli, influences audio-visual speech perception (Welch & Warren, 1980). We speculated that by presenting the incongruent stimuli (the female face paired with the male voice), we might enhance attention to the tasks in all participant groups. While every child perceived a mismatch between the speaker and voice, the McGurk effect was not significantly depressed or enhanced. However, there was a trend for slightly stronger fusion responses from all participant groups, which may indicate that a perceptual incongruity between speaker and voice enhances the attention to perceptual cues and leads to more active listening. The trend was the same among control and children with LD. This result is consistent with findings by Green et al. (1991). The authors demonstrated that integration of visual and auditory modalities was not significantly modified by gender incompatibility. They concluded that perceptual normalization of the speech signal occurs early in phonetic processing. Green et al. (1991) and the results from the current study indicate that all of the children in this study, including those with LD, attempted to normalize the speech signal.

Finally, we explored the relationship between McGurk and reading and math skills. We reasoned that if children with LD were having difficulties integrating multisensory cues, this might affect achievement in more complex skills that build on these basic integration processes. Based on correlation coefficients, it was found that children with LD who exhibited a weaker McGurk effect also had lower reading achievement scores and, to a lesser extent, lower math achievement scores. There were fewer significant correlations between the strength of the McGurk effect and academic achievement scores in the young control group, and none in older control children. Significant correlations were found between the McGurk effect, Performance IQ and Full-scale IQ in the older children with LD. These relationships may indicate that auditory-visual integration may underlie cognitive processes associated with language and math learning. While the correlational data were derived from a small number of participants, the findings warrant further attention and could result in a better understanding of learning disability subtypes.

In summary, the result from this study indicates that children with LD have difficulties with multisensory integration specific to auditory-visual speech perception. Moreover, auditory-visual speech perception did not become stronger with experience and development in children with LD, as it does in typically developing children (Massaro et al., 1986). More research is required to support the hypothesis that children with LD may lack intersensory corticocortical connections of association areas, related to difficulties in storing representations or learning auditory-visual associations (Massaro, 1984; Massaro et al., 1986; Welch & Warren, 1980).

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Author Note

Correspondance concerning this article should be addressed to Carol Boliek, PhD, Department of Speech and Pathology and Audiology, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Alberta, T6R 2V8. Email: carol.boliek@ualberta.ca.

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