論　文

How Might Specific Language Impairment (SLI) and Sensorineural Hearing Loss (SNH) Shape Children's Learning to Read and Spell?

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特異的言語発達障害（SLI）と感音性難聴（SNH）が子どもの読み書きの学習に与える影響

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This essay aims to compare specific language impairment (SLI) and sensorineural hearing loss (SNH), and to identify how these developmental disorders might shape children's learning to read and spell, which will, in turn, shed light upon a satisfactory understanding of how these skills typically develop in childhood or later (Hulme & Snowling, 2009).

Keywords: specific language impairment (SLI), sensorineural hearing loss (SNH), developmental disorders, reading and spelling in childhood

1. Introduction

As Romani, Olson, Di Betta (2005) argued, reading-and-spelling disorders in early childhood are developmental and distinct from adults' acquired reading and spelling disorders. Thus, understanding how children's experience might shape their reading and spelling is critical in education. It will challenge to explore how developing children's brain modulates themselves to maximize outcomes (e.g., expressed speech or written spelling) as the brain grows typical or atypical trajectories from childhood through adolescence (Butterworth & Tolmie, 2014).

Importantly, atypical development in reading and spelling highlights aspects of experience-dependent brain plasticity (e.g., schoolwork), allowing us to understand the developmental process of productive language in the brain in early to middle childhood, even if one such aspect is "not necessarily obvious in the wider population" (Knowland & Donlan, 2014, p. 135).

Writing is such a complex task that requires coordination of comprehensive literacy skills, including, but not limited to, semantics, syntax, spelling, and even writing (spelling) conventions

(Puranik, Lombardino, & Altman, 2007) or orthographies (Marinelli, Romani, Burani, & Zoccolotti, 2015; Treiman & Kesser, 2005). Thus, spelling, as well as reading, is an asset to children's language development and education. Without a capacity to write with a certain level of understanding of language (by listening or reading), a growing child could scarcely become literate (Treiman & Kessler, 2005).

One explanation of how poor spellers are shaped (or learn) by experience to read and spell is traced back to relatively earlier poor production connected to linguistic comprehension in childhood (e.g., Briscoe, Bishop, and Norbury, 2001). Specific language impairment (SLI, Tomblin, Records, Buckwalter, Zhang, Smith, & O'Brien, 1997) is one such example, although there is a dispute in terms of definition (Hulme & Snowling, 2009), identification (Leonard, 1998), and genetic origin (Bishiop, Adams, & Norbury, 2006).

On the other hand, hearing loss develops in deaf and hard-of-hearing (DHH) children (Lederberg, Schick, & Specer, 2013), such as sensorineural hearing loss (SNH), or the chronic otitis media (OM, Winskel, 2006), which gives insight for a poor phonological, as well as poor memory-retention, a process for the vocabulary (spelling) learning, which children's compensatory reading and spelling experience shapes (Briscoe et al., 2001).

In this essay, I review how reading (decoding) and spelling (coding) are related to each other in literacy development (Gough & Tunmer, 1986; Treiman & Kessler, 2005) based on the dual-route (DR) model of spelling (Houghton & Zorzi, 2003). Then, exploring how SLI and SNH (e.g., Briscoe, Bishop, and Norbury, 2001) share, or do not share, developmental connections of reading and spelling, differences and similarities underlying the two impairments are discussed. Finally, I will integrate the review to identify developmental disorders of reading and spelling that shapes children's literacy learning in terms of neurobiological, cognitive, and behavioural outcomes of children challenged by SLI and SNH.

2. How Does Reading Related to Spelling: The Theories

Research has shown evidence that understanding learning to be literate requires us to envision how experience shapes children's reading and spelling (Goldberg, & Lederberg, 2015; Puranik, Lombardino, & Altman, 2007; Snowling, & Hulme, 2005; Steven, Maya, Sommer, Susan, & Pélagie, 2007; Treiman & Bourassa, 2000). In other words, reading and writing (spelling) intertwine themselves in early language learning. Both necessitate and affect each other to suffice for successful literacy development in childhood and later (Treiman & Kesser, 2005).

However, the extent to which the combination of spelling and reading can cause children's difficulties is different from language to language; that is, the sound-to-symbol correspondences vary

according to writing systems (e.g., logography [Chinese], syllabary [Cherokee], or alphabet [English]), which, in turn, directly affects written language and reading. A spelling rule (i.e., orthography) in English, for example, is a complication for children with dyslexia, whilst that in Italian is less complicated for children with dyslexia at the same age (Marinelli et al., 2015). It denotes a deeply connected relationship between spelling and reading learning that should be learned by preschool- and school-aged children.

Trieman and Kessler (2005) argued that the reading process (i.e., transforming print to speech, or print to meaning) is subject to the two decoding systems of language structure: the phonological system and the morphological system, and that both two systems, as well as the subsequent comprehension, are essential in practice for children to learn reading and spelling. A phonological system refers to a system in which they decode print to sublexical or phonological representation (e.g., "[dɔg]" in English and "[inu]" in Japanese), whilst a morphological system refers to children's decoding print into lexical (and semantic) representation (e.g., "dog" in English, represented by an animal kept by a human).

In the Simple View of the Reading model, Gough and Tunmer (1986) extrapolated a productive formalization of reading, where reading (R) is a product of decoding (D) and linguistic comprehension (C) (R = D x C). The formalization successfully highlights these two dimensions of reading. It denotes that understanding is essential for reading to occur; namely, if one cannot comprehend a passage (C = 0), then R on the left-hand side is null (meaningless). Alternatively, learning to understand (decode) determines how much the decoder can read. On the other hand, the formalization also denotes that, even if one can comprehend the passage, the decoder cannot read without sufficient decoding—the situation occurs when the reader is a poor decoder, such as dyslexic children, novice foreign language learners, or children with a congenital hearing disorder.

Hence, the Simple View model roughly predicts different reading impairments in contrast to each other: that is, (1) atypical poor decoders—children with dyslexia or with sensory difficulties such as mild SNH, who have relatively adequate linguistic comprehension and intelligence; and (2) atypical poor comprehenders—children with SLI or with poor comprehension, who have relatively adequate reading accuracy (Nation, Clarke, Marshall, & Durand, 2004).

Individual variability of reading and spelling difficulties in early childhood can also be theoretically explainable by the "dual-route (DR)" model (Castles, 2006; Ziegler, Perry, & Coltheart, 2000; Houghton & Zorzi, 2003; Romani et al., 2005; Tainturier, & Rapp, 2000) For example, Houghton & Zorzi posited two routes in the DR model of spelling. These are (1) a route from phonological input to sound-spelling conversion (PS route) and (2) an orthographic output lexicon route (OL route), which are successful for predicting atypical poor reader's error-prone typing (or handwriting) while they are spelling (Figure 1).

OL route allows lexical access along with semantic access for meaning retrieval. If it is impaired, children may have more difficulty learning irregularly-spelt words due to regularization errors—oversimplification caused by a disability of whole-word access would occur. The situation would result in poor spelling for irregular words. Alternatively, the PS route allows direct conversion in a piecemeal fashion from phoneme (sound) to grapheme (spelling). With impairment, children may have difficulty in correctly spelling novel words and nonwords, which results in poor spelling for new words and nonwords and less frequent words (e.g., "yacht"), even though they spare recognition of familiar words (e.g., yacht as a boat used for racing or pleasure). It happens irrespective of the consistency of orthography (Bishop, North, & Donlan, 1996; Forum for Research in Literacy and Language, 2012; Romani et al., 2005).

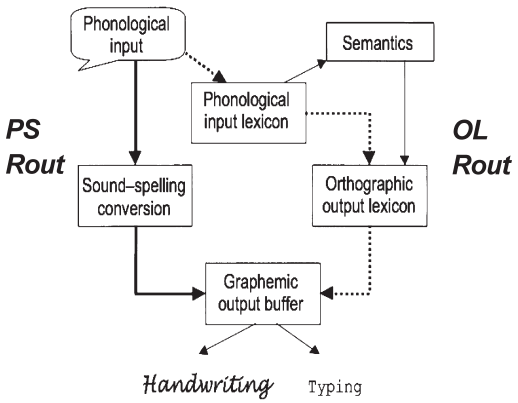

Figure 1　A "Dual Route " Model of Spelling. Dotted arrows show the lexical route (OL route), and bold arrows the sound-spelling conversion route (PS route). Direct input via semantics is also shown (Houghton & Zorzi, 2003).

In short, both the Simple View model and the DR model suggest the cognitive connection between reading and spelling and the apparent similarity across SNH and SLI, as well as the difference between the two that differentiate trajectories in their literacy (reading and spelling) development: that is, (1) a similarity where both are related to nonword or less frequent word deficit, and (2) a difference where children with SLI might be poor comprehenders, whilst children with SNH might be poor decoders (Bishop et al., 1998; Briscoe et al., 2001) (Table 1).

3. Specific Language Impairment (SLI)

Specific language impairment (SLI) refers to "a form of developmental language impairment in which children demonstrate unexpected difficulties with the acquisition of spoken language" (Tomblin

et al., 1997, p. 1245). Tomblin et al. summarized an “exclusionary condition” for SLI in terms of a consensus that SLI shall not be developmental disabilities such as mental retardation, autism, or neuromotor impairments, nor can it be a persistent hearing loss (p. 1246). However, Aram, Morris, and Hall (1993) noted that far less consensus is met for the inclusionary conditions for SLI diagnosis due to a discrepancy between the clinical diagnosis and the standardized operational criteria. Thomas (2005) also mentioned that cognitive level explanations of SLI are yet to reach a consensus, questioning whether a neural substrate of SLI is "language-specific" (p.438).

Table 1 Summary of Disorders and Individual Difficulties

Developmental Disorder	*Simple View Model*		*Dual Route Model*	*Predicted Individual Difficulties*	
	Coding/ Decoding	Comprehen-sion	Route	non-word less frequent word	irregular word
Dyslexia	✓		*PS*	✓	
	✓		*OL*		✓
SLI		✓	*PS*	✓†	
		✓	*OL*		✓
Poor Comprehension		✓	*PS*	✓	
		✓	*OL*		✓
SNH	✓		*PS*	✓†	
	✓		*OL*		✓

Note. †A similarity lies between SLI and SNH (in this case, they might produce difficulties in spelling nonwords rather than irregular words). A tick represents difficulty, whilst a blank cell refers to no or fewer difficulties. *PS* refers to the phonological sound-spelling route, whilst *OL* refers to the orthographic output lexicon route in the DR model of spelling.

So, it is "specific" because the co-occurrence of language impairment and apparent unimpaired intelligence exist for the nonce (Knowland & Donlan, 2014, p. 145). In addition to the terminology, there is nominal confusion among researchers, clinicians, as well as policymakers and educators. Hulme and Snowling (2009), for example, brought an issue of concern about DSM-IV (American Psychiatric Association, 1994), categorizing SLI as an impairment suffered by children with a developmental disorder that should comprise their substandard oral language skills. According to Hulme and Snowling, DSM-IV includes children who might be clinically diagnosed as SLI in the category of "Communication Disorders," which would, however, bring about confusion owing to relatively broader categorization including pathologies such that are not often associated with a disorder of language development (e.g., dysphasia).

Symptomatic cases of SLI are also elusive to identify due to considerable heterogeneity in the pattern of language difficulties that children with SLI would present (e.g., speech difficulties, pragmatic difficulties, or poor expressive language skills). Yet, concerning the prevalence and persistence of SLI, researchers (e.g., Hulme & Snowling, 2009) have arguably agreed that SLI is a

developmental disorder that persists throughout early childhood to interact with the environment (e.g., socioeconomic status, SES), showing further declines as age increases, during which the symptom develops across all language skills as well as broader cognitive skills. This trend suggests a strong connection between reading and writing to onset learning time at school, which relates to language production (e.g., spoken expression and spelling and written expression).

In the meantime, there has been a discussion about the parallel relationship between SLI and poor comprehension (Nation et al., 2004). Nation and colleagues stated that the two impairments demonstrated that poor understanding is at least quantitatively, if not qualitatively, distinct from SLI. Specifically, the prevalence of SLI appears different from poor comprehension, followed by frequent references by speech-language pathologists (Leonard, 1998; Yuill & Oakhill, 1991). Furthermore, evidence revealed by studies is mixed; despite the overlapping extent of comprehension difficulties that study found between SLI and poor comprehension, there is an individual variation with controversial results in phonological skills (e.g., Cain, Oakhill, & Bryant, 2000; Nation el al., 2004).

Also, despite the well-documented evidence of the genetic influence as in twin studies (e.g., Bishiop, Adams, & Norbury, 2006), the underlying deficits of SLI are not clear yet and in continuing debate (Knowland & Donlan, 2014; Hulme & Snowling, 2009). In stark contrast to the aetiology of a highly distinctive syndrome such as Down syndrome (i.e., an extra copy of chromosome 21), SLI does not show a clear division between normality and abnormality in its aetiology but shows complex polygenic interactions (Hulme & Snowling, 2009), which made a clinical definition of SLI extremely elusive (Bishop, 2014). However, from a perspective of educational neuroscience, Knowland and Donlan summarized those difficulties of SLI are attributable to the presence of specific and independent effects on "(a) a general measure of phonological memory and (b) a measure of morphosyntactic skill" (p. 145). This recap presents a similar view to Treiman & Kessler (2005).

4. Sensorineural Hearing Loss (SNH)

Researchers consider Language development is the most significant area challenged by hearing loss in deaf and hard-of-hearing (DHH) education (Lederberg, Schick, & Spencer, 2012). Notably, children with hearing loss increase the risk of language delay and disruption. Moreover, despite the extensive severity of hearing loss (from 26 dB [mild] to 91 dB~ [profound]), Fraser (1974) revealed that nearly 50% of British school children with severe to profound hearing loss had a genetic origin. A large variety of chromosomal aberrations and mutations causes it; however, 90 to 95% of children with hearing loss are born to parents with normal hearing. The findings suggest the familial advantage of DHH children whose parents are hearing impaired, precociously with Cued Speech (Leybaert, 2005).

A problem of SNH lies in the inner ear: the damage of the acoustic stimulus into nerve impulses

impairs the transforming hair cells of the cochlea or the auditory nerve (Leybaert, 2005). Whilst conventional prostheses (hearing aids) aid solely, albeit not exclusively, children with adequate residual hearing, the enhanced hearing technologies aid cochlear implantation for children with severe to profound (71 dB–91 dB or more) hearing loss to compensate for deficit via electrically stimulated auditory nerve (Dillon, De Jong, & Pisoni, 2012; Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007).

In addition, there is evidence that the inner ear is vulnerable to chronic suppurative otitis media (Papp, Rezes, Jókay, & Sziklai, 2003) with a significant correlation to SNH (Kolo, Salisu, Yaro, & Nwaorgu, 2012). Chronic otitis media (OM) is a common pediatric illness of middle ear infection that develops most frequently during the crucial first three years of life, which could have a potential early reverse effect on language and literacy skill development (Winskel, 2006). Children suffering from OM, for example, achieved lower scores than non-OM children in phonological awareness skills such as alliteration, rhyme and nonword reading, and expressive vocabulary. Likewise, variation with persistence (after three years of age through ten) in phonological awareness is also evident as it is so in hearing children (Shapiro, Hurry, Masterson, Wydell, & Doctor, 2009). Thus, these findings imply that an early OM infection, which may cause children's severe coding disability, should pose a risk for school-aged children's debilitating language development and later aberrant literacy development.

As Leybaert (2005) argued, given speech-production skills often associated with sufficient residual hearing, it would be more likely that the ongoing processing of the input stimuli should determine the adequacy of these children's phonological patterns rather than speech-output (productive) processes. Individual differences concerning phonological codes by children with SNH thus predict speech intelligibility (Leybaert, 2005). In other words, the extent to which the hard-of-hearing readers use phonology during written word processing is a critical factor for their later language and literacy development. Gathercole & Martin (1996) demonstrated that interactive processes in phonological (working) memory played a cognitive role in the individual differences in the variability of short-term memory (discussed later).

Therefore, children with severe and profound hearing loss might show impaired spelling processes, as the phonological representations in these heavily challenged children are profoundly poorer than those in children with normal hearing. Namely, due to the deprivation suffered at the early stage of their life, children with SNH use less optimal phonological code than children with normal hearing do.

Importantly, however, research has presented increased countervailing evidence that SNH-challenged children with good comprehension (reading skills) arguably get access to coding/decoding in a compensatory fashion that covers deficits in phonological representations (Leybaert, 2005; Romani et al., 2005). In other words, their coding process functions not in the phonetic dimension (as in the normal readers) but the linguistic dimension, using alternatives, such as lip-

reading (Dodd, 1976), speech articulation (Conrad, 1979), or fingerspelling (Padden, & Le Master, 1985).

In short, these findings suggest that early clinic and educational intervention is significant for avoiding developmental delay. There are opportunities for children with SNH to use compensatory strategies (e.g., evoking sensitivity of orthographic patterns). This compensation partly happens on top of the deprivation in the history of experience (Fern-Pollak & Masterson, 2014).

5. Impact of SLI and SNH on Children's Reading and Spelling

From the perspective of neuroscience in language development (Knowland & Donlan, 2014; Fern-Pollak & Masterson, 2014), Table 2 summarizes the relationship between neurobiological (genetic origin, auditory processing), cognitive (phonological, and morphosyntactic, processing), and behavioural (nonword task) outcomes (writing difficulties) with two developmental disorders (SLI and SNH).

Table 2 Neurobiological, Cognitive, and Behavioural Outcomes

Developmental Disorder	*Neurobiological*		*Cognitive*		*Behavioural*
	Genetic Origin	*Auditory Processing*	*Phonological Memory*	*Morpho-syntactic Skill*	*Nonword Task*
SLI	✓	?	✓	✓	✓
SNH	✓	✓			✓

Note. A tick represents difficulty or deficit, whilst a blank cell refers to no or less difficulties. The question mark refers to an existence of individual difference that shows such a deficit.

The table suggests that, in SLI, there is a wide range of reduced or absent cognitive (i.e., cortical) outcomes in sentence production (morphosyntactic skill) and short-term memory (phonological memory), whilst there is a deficit in neurobiological engagement (auditory processing, e.g., brainstem response) in SNH. Interestingly, there is an individual difference in SLI, which shows the similar, albeit still controversial, intensity of auditory processing to SNH (Briscoe et al., 2001; Talall, 1976, detailed below).

However, both SNH and SNH have genetic origins and deficits in nonword processing. The commonality suggests that a variety of individual learning in children with SLI and SNH children be susceptible to the impact of gene expression on their early reading and spelling experience, arguably, in terms of (1) a low-level auditory perceptual impairment (e.g., Bishop et al., 2010; Knowland & Donlan, 2014), and (2) vocabulary (spelling) learning that refers in essence to new words (i.e., novel speech sounds) learning.

Briscoe and colleagues (2001) study shed light on such a complex picture. It compared children with SLI and mid-to-moderate SNH with the two controls who matched receptive vocabulary and chronological age (5–10 years) to the respective groups. The argument is that, despite a considerable variation in the SNH group, children with SNH did not show the pervasive cognitive difficulties with language (grammar, vocabulary) and literacy (nonverbal reasoning) that characterized children with normal hearing SLI. However, as the DR model predicted, both groups had a similar pattern on the phonological tests (discrimination and awareness). Most interestingly, both did share a pronounced deficit in nonword repetition.

Nonword repetition is well known and documented as a measure to predict language learning and relevant difficulties (Bishop et al., 1998; Bishop, Hardiman, & Barry, 2010; Coady & Evance, 2008; Edwards & Lahey, 1998). Poor nonword repeaters are highly heritable, indicating that the children should be at risk for literacy problems (Bishop, 2001; Bishop et al., 2010). Gathercole and Baddleley (1990) applied a cognitive model of working memory for comparing phonological memory skills between children with SLI and verbal (and non-verbal) matched controls. They demonstrated that, despite the similar productive latency across groups, children with SLI presented a failure in phonological coding in so-called immediate memory and that the subvocal processes of the impaired children were inadequate to that of normal children.

Briscoe and colleagues' (2001) overall results showed no close link between phonological impairment and the other language (literacy) measures. The finding suggested that problems among these children suffering SLI/SNH were common in domain-general, phonological processing ("phonological memory," Knowland & Donlan, 2014, p. 145, see also Thomas, 2005), but not language- or literacy-bound, dissociated from other language skills.

Given that human's phonological memory plays a part in the learning of vocabulary and syntax (Baddeley, Gathercole & Papango, 1998; Briscoe et al., 2001), core cognitive limitations in the capacity of phonological short-term memory would possibly explain difficulties in the variability of children with poor comprehension (SLI), as well as of children with poor nonword repetition (SNH), which might eventually shape the poor reading and poor spelling in these children suffering SLI/SNH. However, as Briscore et al. (2001) mentioned, it is yet to be known well and theoretically controversial whether the impulse of phonological function in language development is rooted in higher-order cognitive constraint (Baddeley, Gathercole & Papango, 1998) or low-level auditory perceptual impairment (e.g., Tallal, 1976). No clear validation for what causes the cognitive overlapping in children with SLI and children with SNH (Bishop, 2001, 2014; Thomas, 2005).

Moreover, the prediction by the Simple View model shows the essence of inference for reading and spelling because inference (reasoning) is deeply connected to comprehension through cortical functions in the human brain (Fugelsang & Mareschal, 2014). Although there was a considerable

variation in the results of Briscoe et al. (2001), the children with SNH did not show difficulties with grammar, vocabulary, and nonverbal reasoning, whilst children with SLI manifested a significant reduction in all those inferential functions. Thus, poor inferential (cortical) competence in SLI might sweep over the neurobiological factors (e.g., subcortical auditory processing), leading to reduced reading comprehension.

Further study is needed to clarify whether deficits in auditory processing are attributable to the phonological impairments commonly seen in SLI and SNH, e.g., pinning down the cause of the impairments that emerged in SLI. Since auditory deficits (Tallal, 1976) derive from the subcortical function such as in the cochlear (hair cell) or brainstem (inferior colliculus) (Tierney & Kraus, 2013), They do not seem to fully account for the whole "gamut of language and literacy difficulties seen in this population" (Briscoe et al., 2001, p. 339).

6. Conclusion

This essay compared SLI and SNH to identify the difference and integrate the similarity. It explored how the experiences that have grown through atypical trajectories of children shape developmental disorders. To conclude, evidence in developmental disorders showed that language and literacy development in reading and spelling is subject to differential shaping (individual variation) of maturational (brain) and experiential (behaviour) factors in early childhood. This in turn generates an experience-dependent compensation in challenged preschool and school children. Hence, an attempt to predict learning to read and spell is crucial to better facilitate struggling readers and spellers at or around reception age.

A common feature of phonological deficits exists in these disorders: both have a genetic origin, showing difficulties with nonword repetition. The deficits indicate enhanced variation traceable to neurobiological engagements: subcortical auditory and cortical inferential processing. SLI might be domain general-bound, whilst SNH could be auditory specific. Thus, one view shows that the phonological deficit poses more severely impaired children with an increased possibility of sound-to-letter, sublexical, coding/decoding problems for both types of children in early childhood, on reading and spelling difficulties (e.g., learning of new words or less frequent words).

On the other hand, a differentiated feature between two categories (SLI/SNH) exists in the variability of cognitive difficulties. Children with SLI show phonological memory difficulties as well as reduced morphosyntactic skills, both of which, being cognitively intertwined, result in comprehension deficits that form a characteristic feature of SLI, such as debilitated phonological (working) memory or poor and delayed reading and writing skill; however, children with SNH show no such deficit.

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