Specific Language Impairments and Overlap Sensory Integration Disorders – Are Additional Therapeutic Approaches Warranted?

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Abstract

Specific Language Impairments and Overlap Sensory Integration Disorders –
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Specific Language Impairments, a class of language disorders characterized by delays to language acquisition in the absence of hearing loss or other obvious developmental delays, are often identified during the preschool years. While some initial difficulties seem to resolve as a child grows, current research identifies Language Impairments as a risk factor for to later academic difficulties often in reading and writing. According to the literature on Language Impairment, most proposed remediation focuses strictly on types of interventions tied directly to language acquisition and usage, such as phonological training as provided by Speech Language Pathologists (SLP). Literature in other fields, however, is emerging that suggests that the neurological problems leading to language impairments and an SLI diagnosis may not affect language areas in isolation after all, but also affect other areas of functioning, albeit in more subtle ways, due to impaired sensory integration. Research in the realm of neuroscience of learning suggests that such corollary cognitive difficulties should be taken into account when

providing remediation. These research trends in other fields backs what educators in the field have known and practiced for a while. To wit, they lend credence to an individualized approach to special education for children with language difficulties.

Keywords: SLIs, dyslexia, reading, cognition

The term Specific Language Impairment (SLI) is used to identify any communication disorder of a developmental nature that is characterized by specific delays in language occurring when no other reported developmental delays are co-occurring (Bishop & Snowling, 2004). It is a catch-all term that includes various childhood impairments of speech, from childhood apraxia of speech (marked difficulty in coordinating the motor patterns of speech not due to general motor deficits), to expressive language, receptive language, and pragmatic language, all of which cannot be explained by corresponding delays in other cognitive domains (Berninger, 2015; Bracken & Nagle, 2007; Messer & Dockrell, 2001). That is not to say that children diagnosed with Specific Language Impairment exhibit delays only in the domain of language. Merely, other cognitive or functional difficulties may not rise to the same level of impairment as language. Later in this paper, we will identify certain motor and sensory difficulties that do seem to occur with significant frequency among children identified with SLI, albeit placing these children at the low end of the normal developmental range for said motor/sensory difficulties. Whether these recent findings suggest that the diagnostic category of SLI does not precisely describe the origins and repercussions of language delays, or it is a catch all category that is often used before more appropriate diagnoses occur on an individual level, it remains to be seen.

While the learning arc of children with SLIs resembles that of their normally developing peers, there is much evidence suggesting that starting off school with a language delay is likely to affect later academic prowess. The majority of children identified as having an SLI in preschool or kindergarten do gain language skills through various individualized remedial therapies. However, many children with an SLI do not simply “catch up” to their peers. Rather continue to lag in social and academic achievement when compared to them (Catts, Bridges, Little, & Tomblin, 2008). Thus having an SLI is considered to be a risk factor for poor academic

outcomes (McClelland, Morrison, & Holmes, 2000). Problems with oral language learning that surface in the preschool years (late talking for single words, combining words, and communicating in syntactic structures) may continue during the school-age years and often are accompanied by emerging problems in written language, "especially with syntax, morphology, text-level discourse, and sometimes word finding. Listening comprehension, reading comprehension, and written expression of ideas in composition tend to be impaired." (Berninger, 2015, p. 235) Language acquisition, after all, involves multiple sensory modes: we learn language by using and imitating motor movements in the mouth, by listening to other speakers, by perceiving and recognizing written language around us, and by using our hands to reproduce and create our own ideas through written language (Berninger, 2015). This interconnected system in turn is supported by a network of cognitive processes supporting its integration (Berninger, 2015)

A growing sophistication in identifying and treating speech and language impairments, (i.e., learning difficulties when acquiring oral language skills), has allowed educational researchers to confirm that there is a strong correlation between childhood developmental language disorders and increased likelihood of later difficulties in learning to read and write by third or fourth grade (Catts, Fey, Tomblin, & Zhang, 2002; Hulme & Snowling, 2014; Messer & Dockrell, 2001; Skibbe et al., 2008).

As a result, the focus of research on SLI and language acquisition and growth is and should be shifting. Currently, said focus is in understanding the origin of such disorders, as well as how they affect preschool children (since this is the age when children are most likely to be identified as having an SLI). This paper argues, using multidisciplinary research, that a further goal should be to identify promising early interventions aimed at targeting and affecting

neuroplasticity (i.e., the capacity of developing brains to rewire themselves for better cognitive performance) in children who have SLIs as well as associated developmental disorders. Such interventions should not be limited just to affecting speech and language acquisition, but to targeting other affected aspects of learning on an individual basis.

Educators' Current Approaches to Language Acquisition

Traditionally the focus for early childhood educators has examined correlations between the number of words young children are exposed to and cognizant of, and how it translates into later academic success (Hart, 2000; Hart & Risley, 1992; Risley & Hart, 1995). Specifically, early research in early childhood literacy and school readiness has often tend to focus on whether parental income and socio economic status affects language acquisition in all children, whether neurotypical or not (Hart & Risley, 2003).

In such a climate, a seminal study conducted on siblings of children in an early childhood program and their economically advantaged age peers, Hart and Risley (1992) collected observational data on 40 children and their families between the ages of 0 and 3, in order to analyze the incidental language interactions between parents and children, and their influence on the children's later command of language (Hart & Risley, 1992; Risley & Hart, 1995). Within the study, Hart and Risley measured overall parental activity dedicated to language learning, finding that there was a correlation between SES and the amount of direct language instruction from their parents and the children's performance on post-study measures of language acquisition (Hart & Risley, 1992). When measuring the performance of the parent as a social partner (how the parent reacted to child initiated speech, and how the reaction sparked a conversation), SES had little to no effect on the frequency of such social conversions, or the difference between the parent's MLU and the child's MLU, nor did it affect subsequent

performance by the child on the IQ test administered at the end of the study (Hart & Risley, 1992). When the "contentive quality of parents' utterances" (the amount of language that implied parental disapproval when it came to a child's activities) was examined, it emerged that children in families with low SES had more frequent negative interactions with their parents, usually involving a parent discouraging a child from doing or saying something, and such negative interactions in turn were strongly correlated with IQ performance (Hart & Risley, 1992).

More importantly, the effects of early language quantity and quality seemed to extend beyond the three-year mark: Risley and Hart (1995) looked at data from a study measuring children's performance on standardized tests for third graders which had recruited 29 of the 42 families in their original study, assessing the children with a variety of cognitive tests, including the Peabody Picture Vocabulary Test-Revised (PPVT-R), the Test of Language Development-2: Intermediate (TOLD), and various of its subtests (Risley & Hart, 1995). Vocabulary growth for each child as recorded at the age of 3 was indeed predictive of performed on these cognitive measures administered five years later (Risley & Hart, 1995). Of note, there was a statistical gap of over 30 million words between children with low SES, and children whose SES fell in the upper income category (Hart, 2000; Hart & Risley, 2003; Risley & Hart, 1995). This striking difference appeared to be carried into the children's academic performance in third grade (Hart & Risley, 2003; Risley & Hart, 1995). Simply put, the foundations laid down by a host of environmental factors, chiefly the quality and quantity of language interactions between parent(s) and child, appeared to be predictive of later academic achievement. Enrichment, the authors of this longitudinal study concluded, should start earlier in life for children who are at risk for academic underachievement (Hart, 2000; Hart & Risley, 2003).

Though groundbreaking, this research was not without limitations. The presence of observers, regardless of how much said observers try to disappear into the background, would invariably affect both recruitment and behavior of the families, creating self-selection bias (Hart, 2000; Risley & Hart, 1995). Parents who were less confident in their overall parenting, or parents with children whose behavior was more challenging may be more likely to decline participation (Hart, 2000). All of the families included in the study could be described as "well-functioning": no pervasive dysfunction, stress or abuse was observed (Risley & Hart, 1995). Thus, the findings would be less applicable to children living in greater systemic conditions of disadvantage (Risley & Hart, 1995).

Rindermann and Baumeister (2015)'s recent reanalysis of Hart and Risley (1995)'s data provides an added caution in tempering the predictive level of SES on a child's language performance throughout childhood. In this reanalysis, the data from Hart and Risley (1995)'s study was combined with data in a similar study by Hoff (2003) that explored the interactions of both SES and parental education with a child's academic performance (Rindermann & Baumeister, 2015). The combined data suggests that while parental SES is predictive of children's academic performance, parental education is far more closely correlated with said performance (Rindermann & Baumeister, 2015). Parental educational behavior as a predictive factor of a child's overall gains in language acquisition, may in turn be influenced not by the parents' present economic circumstances, but by the level of education they themselves had attained before becoming parents (Rindermann & Baumeister, 2015).

While the "word gap" theory may not appear to be related to Language Impairments, the idea that such a gap has potentially long ranging effect in a child's education has had long reaching effects in much literacy education, including Special Education. Hart and Risley's

research strengthened an interest in educators as to what environmental and genetic factors may contribute to some children coming into the school environment (kindergarten and beyond) already at a learning disadvantage when compared to their peers (Justice et al., 2015; Morgan, Farkas, & Wu, 2011; Paulson et al., 2004). Language impairment knows no SES or other societal boundaries, as children living in poverty as well as children living in more economically advantaged condition may be affected by one. However, having a language impairment may very well amplify the effect of other economically and culturally dependent environmental barriers, thus causing children experiencing both to fall even further behind when an intervention does not focus on their specific needs (Morgan et al., 2011). Furthermore, where SLI are concerned, even meeting a goal of parental exposure to rich language may not be enough once their beneficial nature is moderated by the existence of a language impairment (Rice & Hoffman, 2015).

As more and more educational researchers shifted their focus to whether and how intellectual disabilities in earlier childhood are also predictive of later academic weaknesses, literature began to emerge that suggested definite correlations between an early childhood diagnosis of SLI, and later reading and writing problems (Catts, Adlof, Hogan, & Weismer, 2005; Catts et al., 2002; Skibbe et al., 2008).

Pennington and Bishop's study (2009) provides the best analysis of the interrelations of disorders of speech, language, and reading and is particularly illustrative of the issue. Speech sound and other language disorders are very often diagnosed as co-morbid, but there is less evidence for a co-morbidity between language impairments and reading disorders or writing disorders (Pennington & Bishop, 2009). However, an overlap between the two conditions exists, as demonstrated by the existence of studies that compare the performance of children affected with one disorder to that of some affected with both (Catts (2002) as cited by Pennington &

Bishop, 2009). It also appears that a co-morbidity of speech sound and language impairments carries an increased risk of a later identified reading disorder (Pennington & Bishop, 2009). A look at cognitive models for all three disorders suggests that underlying all of them may be a phonological deficit (Pennington & Bishop, 2009). Poor phonological processing on part of a listener/language performer is bound to cause problems both in everyday conversation and in reading and writing (Nittrouer & Pennington, 2010; Pennington & Bishop, 2009). However, this common deficit is not in and of itself sufficient to guarantee co-morbidity; it is more likely that multiple deficits in cognition cause said co-morbidity (Pennington & Bishop, 2009).

SLI, Sentence Comprehension and links to Learning and Reading Disabilities

A focus on SLIs in education is warranted because it can be predictive of later academic, social, and behavioral risks (Catts et al., 2002; Mashburn & Myers, 2010; Mcclelland et al., 2000; Paulson et al., 2004). Many children with SLI are documented as having difficulties in sentence comprehension tasks at a higher rate than comparable age peers (Leonard, Deevy, Fey, & Bredin-Oja, 2013). Two schools of thought seek to explain the problem: the first posits that grammatical principles necessary for such tasks emerge late in children with SLIs, whereas the second posits that the tasks are difficult because they tax the cognitive capacity of children with SLIs more than comparable age peers (Leonard et al., 2013).

Leonard et al. (2013), separated these two variables in a study where children with SLI were compared to two control groups on a variety of sentence tasks where they were asked to match three sets of sentences with an appropriate picture illustrating it, with the sentences being grouped into three conditions: low cognitive demand, medium cognitive demand, and high cognitive demand, based on their complexity. The control groups were respectively one comprising typically developing children who were of the same age as the group studied, and

another that included younger children who had been tested and found to have sentence comprehension levels in line to that of the children with SLI group (Leonard et al., 2013). The children in the SLI group had scores similar to that of the younger group when it came to overall performance in sentence comprehension tasks within the study (Leonard et al., 2013). A further analysis of the errors themselves, however, suggested that while the performance of the younger group of children dropped more dramatically in the medium demand condition, children with SLI performed the worst when high demand sentences were introduced (Leonard et al., 2013).

Mashburn and Myers (2010) used longitudinal data from a national data collecting project called the Early Childhood Early Childhood Longitudinal Study—Kindergarten Cohort to see how special education classifications changed over time. In kindergarten, most of the students within the sample who were identified as needing Special Education services had been classified as having a speech or learning impairment (Mashburn & Myers, 2010). By third grade, however, less than 24% of children with an original diagnosis of speech and language impairment were still classified as needing speech services (Mashburn & Myers, 2010). Conversely, the number of children who were designated as receiving learning disability services started out as the second largest category of children receiving special education services in Kindergarten, with the number continuing to rise until by third grade to become the largest category of children receiving services (Mashburn & Myers, 2010). It is important to also note that most other diagnostic categories remained more or less stable over time, thus suggesting that most children who seemingly outgrew language impairments were later classified as experiencing learning disabilities by third grade (Mashburn & Myers, 2010).

Building on Mashburn and Myers (2010), Berninger and May (2011) make the case that for a subset of children who are identified with learning disabilities, the real issue is that they

have continuing problems learning due to the original language impairments they were diagnosed with. These students, designated as having an oral and written language learning disability (OWL LD), do not respond well to therapies targeted towards dyslexia and dysgraphia due to the underlying language impairments (Berninger & May, 2011). Targeted therapies that encompass more language learning supports (such as providing explicit explanations of the complexities of language sounds vs. representational lettering) appear to be more successful strategies (Berninger & May, 2011).

However, scant research exists as to the long term educational effects of SLI. The existing evidence suggests that the language gap between children with an SLI and typically developing children never fully closes and can potentially continue well into young adulthood (Rice & Hoffman, 2015). A longitudinal study conducted by Rice and Hoffman suggests that children identified as having an SLI continue to lag behind in vocabulary acquisition when compared to unaffected children (Rice & Hoffman, 2015). It is possible that such a lag was maintained as a result of poorer reading skills combined with existing language acquisition difficulties relating to processing and retaining knowledge (Mashburn & Myers, 2010). More importantly, Rice and Hoffman (2015) found that maternal education only had a modest effect in the children's rate of language acquisition. Even exposure to rich language from a primary caregiver would not likely mitigate the effects of specific language impairments when it came to vocabulary acquisition, one of the predictors for later academic success (Rice & Hoffman, 2015). That being said, the likelihood that a child with SLI will later develop reading disorders hardly applies uniformly to all children diagnosed with a language impairment because they are a rather heterogeneous group, presenting with a plethora of difficulties that seem to affect some parts of language and not others (Fogle, 2008). Such difficulties are often variable at the individual level:

children with SLI are as much unlike one another in how their difficulties present as they are like as a group, given that those difficulties often involve not just language, but also affect language-based socialization (Rice & Hoffman, 2015). As a general rule, no individual child can and does fit into a neat diagnostic category, and even when specific problems like a SLI are diagnosed, there may be other problems a child is concurrently experiencing that do not rise to the level of official diagnosis, but nonetheless will impact all cognitive processes, especially those that are more readily identifiable. (Berninger, 2015)

Because of that heterogeneity, researchers have also begun to explore and categorize different types of language impairments, in hope to be able to differentiate children into groups that might more readily identify risk for later reading difficulties (Justice et al., 2015; Pennington & Bishop, 2009). This research may require a more nuanced understanding of language processes that encompasses not just language production, but how language acquisition occurs at the neurological level as will be explained below. Incorporating an understanding of language production at the neurological level in children suffering from SLI may help identify how atypical development in specific brain regions may yield to language impairments and other disorders that may co-occur (i.e., when, where, and how an association between SLI and other development occurs).

A primer on the neurological underpinnings of language production

Throughout years of research, neurologists posit that while there are a few areas within our brain that are specialized in the creation and processing of language, there is no centralized processing areas dedicated to language. Rather, an equilibrium in the functioning and efficacy of different language areas is key for normal language development. While the process of language

is decentralized, a few areas have been identified as specialized in key areas contributing to language development.

Broadmann's areas (hereafter BA) 44 and 45, also known as Broca's area, is identified as the primary area responsible for language production (Saletta, Gladfelter, Vuolo, & Goffman, 2015). Damage to this area often affects a person's ability to process language sequentially, and therefore produce correct sentences (Saletta et al., 2015). Given its proximity to the primary motor cortex, lesions or abnormality to BA44 will also affect a person's ability to process other people's action sequentially, as well affecting a person's ability to copy other people's sequential movements, both in a language, and non-language related capacity (Saletta et al., 2015). This will become salient later in this paper, once we discuss associated motor and sensory problems in children with SLI.

Other areas of the brain also contribute to language processing, though they are more likely to provide ancillary support: the cerebellum supports content processing (Van Dun, Manto, & Mariën, 2016) and basal ganglia and hippocampus support, respectively, procedural and declarative memory while a person is engaged in a language task (Gupta, 2011). The fact that language is dependent on several other cognitive tasks and therefore non-language specific areas goes a long way in explaining why language impairments are often comorbid with other developmental and procedural learning deficits, such as ADHD, ASD, and dyslexia (Saletta et al., 2015). Some studies suggest that procedural memory deficits are definitely a hallmark of SLI specifically, and present in other developmental disorders due to co-morbidity (Lum, Conti-Ramsden, Page, & Ullman, 2012; Ullman & Pierpont, 2005).

Parts of the prefrontal cortex having to do with self-regulation and executive functioning are often also involved in the process of speaking and reading, such that children who have an

SLI compare less favorably in tests of executive functioning to their neurologically normal peers (Vissers, Koolen, Hermans, Scheper, & Knoors, 2015). Impaired language and executive function proficiency may in these cases be correlated, in the sense that it's harder for children to self-regulate when they have trouble understanding spoken or written expectations their peers or instructors have. However, there is not enough data to determine whether these two impairments are just correlated, or one is causative of the other (Bishop, Nation, & Patterson, 2014). However such deficits are related enough that a the Procedural Deficit Hypothesis has emerged in the past decade: the idea that language difficulties typical of many SLI almost always involve some abnormality in the areas involved with procedural memory, such as the cerebellum and basal ganglia, (Ullman & Pierpont, 2005) and that compensating for them may tax other cognitive processes such as executive functioning (Vissers et al., 2015). According to the Procedural Deficit Hypothesis (hereafter, PDH), language disorders as exhibited by children diagnosed with SLI are not simply the result of differences in the language areas of the brain, but may in fact be contributed to by additional differences in the sequential processing areas of the brain, as mentioned above (Ullman & Pierpont, 2005). PDH as a hypothesis seems to fit as it also accounts for other cognitive difficulties that children diagnosed with SLI encounter in concomitance with or later in their development, such as being unable to decode written words, or process for meaning and content sequentially (Ullman & Pierpont, 2005). Moreover, it lends itself well to explain how some children with SLI reportedly also appear to have difficulties in executing repetitive motor tasks (Ullman & Pierpont, 2005). Subsequent studies probing the soundness of the PDH have confirmed that procedural memory deficits are definitely a factor in performance during language based cognitive tasks in children identified as having a SLI (Desmottes, Meulemans, and Maillart, 2016; Lum et al., 2012).

More recently, research suggests that efficacy in language processes is not just a matter of certain brain areas being at their peak functioning, but that language prowess is also affected by the way in which said areas of the brain are connected in a particular individual (Vydrova et al., 2015). This research relies on Diffusion Tensor Imaging, or DTI for short, a technique that measures water circulation in the fibers that connect brain regions to one another, i.e., white matter. White matter is responsible in connecting separate areas of the brain to one another, so measuring the activity in this area can give a better idea of how different areas responsible for complex brain tasks communicate with one another (Vydrova et al., 2015). It appears that the brain's functioning is not just about the integrity of specific parts of the brain, but also about the quality of white matter connections between regions (Bassett & Gazzaniga, 2011). There is a threshold to optimal connectivity: if white matter pathways are too diffuse, timely functioning can be impaired; if there is not enough diffusion, certain tasks are going to require more cognitive power, thus hindering any given cognitive performance (Bassett & Gazzaniga, 2011). A good analogy is that white matter is to grey matter what the arterial system is to the heart: the more efficiently the pathways connect, the easier it is for the processes they facilitate to happen.

While only a handful of recent studies have focused on white matter diffusivity in children with SLI (Kim et al., 2006; Mayes, Reilly, & Morgan, 2015; Vydrova et al., 2015), the preliminary evidence suggests that white matter diffusivity is higher in children with SLI and other associated disorders than it is in matched typically developing peers. This suggests that part of the issue, neurologically speaking, is that language areas in the brain of children with developmental language disorders and associated developmental disorders behave differently in order to compensate functioning (Vydrova et al., 2015). Thus, keeping neurological research in mind when talking about SLIs is beneficial in certain ways: knowing which areas or pathways

may be causing diminished functioning in certain individuals that require additional instruction and differential instruction seems to be where the future of the discipline of neurology of education is headed (Berninger, 2015). This in turn is likely to help inform best practices when it comes to students with language disabilities (Berninger, 2015).

Pairing such educational instruction practices with long term studies of brain physiology in learners before and after specific intervention may provide insight on which remedial instructional practices are more likely to induce long lasting neurological changes in a child's developing brain. This phenomenon, known as brain plasticity, suggests the extent to which developmental delays are likely to affect a child depends not just on genetic variance, but also on environmental factors: while many learning disorders may run in families, such gene expression is partly determined by each individual's environment (Fox, Levitt, & Nelson, 2010). This seems to strengthen the argument that while language impairments always have neural and genetic origins, environmental conditions can exacerbate the extent to which the conditions themselves will ultimately become limiting. This interplay is in line with the larger emerging theory of epigenetics, i.e., the idea that nature and nurture's chance interactions are ultimately responsible for many individual differences in humans (Williams, 2013). Epigenetics suggests that during certain periods of development, both prenatal and postnatal, environmental conditions can and do drive brain formation and functioning. Such brain plasticity (i.e., way in which a brain's development adapts to environmental conditions) could be exploited through environmental changes for children who struggle developmentally, however preliminary research suggest that the power of plasticity diminishes over time (Fox et al., 2010). Therefore, the early learning experiences of all children, but specifically of children who are experiencing any language,

behavioral or cognitive delay, seems to be crucial (Fox et al., 2010). As a result, Fox, et al (2010) call for an integration of neurobiology with the study of atypical development of young children.

> "However, whereas studies of atypical development have done an excellent job of describing dimensional phenotypes that underlie disrupted development, it is imperative that we integrate these descriptive concepts with biological constructs of neurodevelopment in order to understand the relevant brain architecture and neurochemical constituents that determine responses to experience that ultimately lead to typical and atypical change" (Fox et al., 2010, p. 28).

While the exact wording is not uniform, the literature in fields other than education points to a substantial overlap of needs and services that are not currently provided to children with SLI or language disorders in general, thus suggesting that in the nexus of language production, all of its components (auditory, cognitive, motor, somatosensory, vestibular) might require support, whereas in educational settings we often focus only on the first two.

SLI, Sensory Integration Disorder, or Both?

In spite of the diagnostic definition of Speech and Language Impairments as a developmental delay not explained by any other physical or developmental cause, SLI can and does occur in tandem with other neurological conditions (Berninger, 2015; Kruger, Kruger, Hugo, & Campbell, 2001; Messer & Dockrell, 2001; Mora & Kashman, 2002; Rechetnikov & Maitra, 2009; Saletta et al., 2015). In such cases, an SLI identification may precede other developmental diagnoses due to the ease of determining whether language milestones stay apace for a child: considerable language delays may be the first indication of problems.

Often, SLIs end up being present with common comorbid conditions, and thus lead to later diagnoses such as Attention Deficit Hyperactive Disorder (ADHD) and Autism Spectrum Disorder (ASD), or Learning Disorders (LDs). In those cases, the comorbid diagnosis subsumes the SLI diagnosis, providing new benchmarks for services (Berninger, 2015).

But what of children who remain identified as primary having a SLI? Might they in fact be weak in other cognitive and motor areas, but falling short of meeting criteria for other developmental delays? If weakness in other developmental areas continues to be attenuated enough, the focus often remains on speech and language production. Yet, motor and linguistic concerns in children may go more hand in hand than previously believed (Rechetnikov & Maitra, 2009; Saletta et al., 2015). Children with SLI show deficits in motor performance when it comes to tasks that require complex motor movements occurring in a sequence (Adi-Japha & Abu-Asba, 2014; Brumbach & Goffman, 2014). There is also a subset of children with SLIs who exhibit only the sensory sensitivities often associated with ASD, rather than the multiple domain delays characteristic of children with ASD (Berninger, 2015). Often, these children are classified as only having a SLI, and receive speech services throughout their schooling. Rather than a case of misdiagnosis, however, recent neurological research suggests that sensory sensitivities (often grouped in the catch all term Sensory Integration Disorder or Sensory Processing Disorder) do occur in the absence of ASD, and may have an entirely different neurological profile (Chang et al., 2014; Owen et al., 2013).

What exactly is a “sensory disorder”? The term Sensory Integration Disorders (later amended to Sensory Processing Disorder or SPD, to emphasize the extent to which sensory stimuli are not actually ignored or overlooked by the sufferers, but rather are not sufficiently integrated as information by their brains) was created by therapist Jean A. Ayers to describe

children with learning disorders who appeared to derive those difficulties from an inability to integrate different sensory information together, whether due to high sensitivity to stimuli, or lacking clear perception of them (Ayres, 1972). Sensory Integration essentially allows different kinds of sensory information to be processed by the brain in order to make sense of the stimuli in question. Some of the different sensory inputs involved might not appear to make sense as contributing information at first, but often different sensory information complement one another (Ayres, 1972).

While the Diagnostic and Statistical Manual of Mental Disorders (version 5) (2013) does not recognize Sensory Processing Disorder as a specific disorder, it does consider overly high or low sensitivity to sensory information to be one diagnostic hallmark of other disorders such as ASD. In other words, Sensory Integration disorder can and does present as a symptom in other neurological conditions. Because of that, many sensory integration issues are often studied and discussed piecemeal by whichever discipline handles specific care of those symptoms: audiology in the case of poorly integrated auditory processes, occupational therapy when it comes to vestibular and other proprioception issues that affect development in subtler sensory-motor ways, and physical therapy where more severe motor disorders are involved. In education, much like in psychology, SID tends to be acknowledged only to the extent to which it affects the learning of any given individual.

As an example, Auditory Process Disorder (APD), sometimes also classified as Central Auditory Processing Disorder (CAPD)[1], is described by the American Speech Language and Hearing Association (2005) as a difficulty in the neural processing of auditory stimuli that is not

[1] Per ASHA's current guidelines, APD has been adopted as the official terminology for the disorder, dropping Central as a requisite word to classify the impairment.

directly related to other cognition problems. On the other hand, APD can sometimes coexist with other disorders (e.g., ADHD, language impairments, and learning disabilities), and yet not be classified as a direct result of these other disorders (Ferguson, Hall, Riley, & Moore, 2011). Berninger (2015) provides a clear illustration of the importance of speech reception and production and its effects on cognition: the aural and oral language systems that support literacy develop during early childhood and form the basis of later learning.

> "From a brain perspective, a *central auditory processing disorder diagnosis* identifies the bottleneck as not being in the ear, part of the peripheral nervous system, but rather in the central nervous system. However, diagnosing central auditory processing disorder is challenging because speech-sound processing involves multiple brain regions in the central nervous system, and any of these regions may be a bottleneck in speech and language processing" (Berninger, 2015, p. 208).

In some sense, APD is a catch-all term very similar in scope to SLI, having to do with hearing disorders absent actual hearing loss. While APD is identified as a nonverbal disorder, children diagnosed with it do exhibit very similar symptoms to children diagnosed with SLIs (Ferguson et al., 2011). Do children who have a Specific Language Impairment diagnosis differ qualitatively in their cognitive performance from children who are diagnosed as having an Auditory Processing Disorder? Ferguson et al., (2011), looked at this question and concluded that the main difference between the two may just be the diagnostic route of identification, rather than starkly different processing issues: if a speech pathologist diagnosed the disorder, it's likely to be labeled as a SLI, whereas if an audiologist identifies the problem, the label of APD is more likely to be conferred to the child presenting with comprehension problems and other co-occurring morbidities. Moreover, Kruger, Yugo and Campbell (2001) found definite overlap between

children who have APD, SLIs, and sensory integration disorder. Because of the different modalities that sensory integration disorder can comprise, it therefore would make sense that remediation of auditory and/or language disorders should take a more interdisciplinary approach (Kruger et al., 2001). Indeed, newer research in auditory processing and perception suggests that children with SLI do indeed experience more auditory perceptive difficulties than their normally developing peers (Cumming, Wilson, & Goswami, 2015). Moreover, these limitation in being able to discern auditory cues may extend not just to speech, but to other sensory domains such as the ability to fully perceive musical rhythm, thus rendering music based speech interventions less than effective for this group (Cumming, Wilson, Leong, Colling, & Goswami, 2015).

Coupling these findings with Ullman and Pierpont (2005)'s formulation of a Procedural Deficit Hypothesis suggests that while children with SLI can indeed receive certain sensory information (one requirement of a SLI diagnosis is that a child's hearing is found after testing to be within the normal range, which would require a physiological reaction to the sounds in the test), it is that the information is not properly integrated with other information necessary to produce and reproduce language, or that all the components are not properly encoded procedurally. It's possible that poor performance in the tasks is a reflection of poor encoding into procedural memory, which allows later automaticity in recall (Ullman & Pierpont, 2005).

In a prior section, we identified that neurologically speaking, there are neurological ties between some language and motor areas (Saletta et al., 2015). Sensory Integration Disorders may be a contributing factor here as well. Vestibular disorder, a specific sensory disorder, is characterized by no majorly impaired motor delays, but rather an overall tendency to be imprecise and clumsy when moving (Mora & Kashman, 2002). Children who are identified as having an SLI are often observed to be clumsier and have a slowed motor response when

compared with typically developing age peers (Brumbach & Goffman, 2014; Leonard & Hill, 2014; Rechetnikov & Maitra, 2009). Could these particular issues be tied to vestibular sensitivities?

Franco and Panhoca (2008) looked for the incidence of vestibular disorders in children who reportedly did poorly in schools and received a variety of academic interventions for them. A vestibular disorder is a neurogenic disorder that affects the ability of children to perceive and achieve balance when moving in space (Berninger, 2015; Franco & Panhoca, 2008). In other words, much like APD, it is a sensory processing disorder (Ayres, 1972). Examining a group of students who performed poorly in school and received academic serves for these problems, Franco and Panhoca (2008) found that almost 75% of them also had enough motor concerns to qualify for a diagnosis of having a vestibular disorder. In their study, Franco and Panhoca (2008) recruited 100 children, roughly half of whom had learning difficulties and disabilities and received services for them. Audiology and otolaryngology tests were performed on all participants to rule out actual physical disabilities having to do with hearing and associated perceptions. Afterward, the remaining 88 participants (43 children with learning impairments, and 45 whose parents reported no such impairments) completed a battery of vestibular tests used to diagnose vestibular disorder. While only 26.7% children without learning disorders tested as having a degree of vestibular impairments, 67.4% of the children in the group identified as having learning disabilities did (Franco & Panhoca, 2008).

Once a vestibular disorder is identified, a person who has a vestibular disorder may benefit by receiving occupational therapy: occupational therapy deals with teaching life and other motor skills sufficient for a person to be independent to people who would intuitively be able to carry otherwise, but cannot due to sensory/neural sensitivities or disturbances (Mora &

Kashman, 2002). A common example of such training consists in having children who display symptoms of gravitational insecurity (i.e., fear of falling) use special weighted swings that increase their sense of security, so that they might start to experience that they are still safe even if they do not always leave their feet on the ground (Mora & Kashman, 2002). However, whether children with SLI do receive occupational therapy for their vestibular insecurities remains dependent on whether they receive co-morbid diagnoses that do meet the criteria for OT interventions.

Summary

In the last quarter century, there has been a groundswell of attention towards developmental childhood delays in general, and Specific Language Impairments are no exception. Much of the attention has focused on early detection and intervention. However, the impact of SLI, both treated and not, on later childhood achievement is still not completely understood. What does emerge based on the data currently being collected and studied, is the importance of not just early intervention, but continued and comprehensive interventions even in cases where the impairments appear to have resolved by kindergarten. Focus thus inevitably shifts towards the practical applications of such a continued vigilance, and to the direction of further research.

The Long-Term Team Approach

What happens once we warrant the assumption that SLI does not occur in a vacuum, but that other developmental issues are often associated with it? As previously discussed, there may be several factors behind language acquisition difficulties in a child: procedural memory impairments (Lum et al., 2012; Ullman & Pierpont, 2005), possible associated executive regulation shortcomings (Vissers et al., 2015), over connectivity in the brain that leads to slowed

cognitive responses (Vydrova et al., 2015), and motor issues that may affect language acquisition in tangible ways (Rechetnikov & Maitra, 2009). We must of necessity explore the idea that early intervention when it comes to SLI should involve more than speech and language remediation, and that students should be followed well beyond the extent to which their first linguistic difficulties appear to be "resolved" or "outgrown".

An effective early intervention, as in with other neurological disorders such as ASD or ADHD, would ideally be tailored to the needs of the individual child. For that to be the case, even children who are only initially diagnosed with a SLI would need to be reevaluated in a timely manner. In the case of children of preschool age, once yearly IEPs might not be sufficient, and comprehensive re-evaluations should occur before a child enters kindergarten. While it may seem to make economic sense to focus on just speech and language acquisition as a barometer of what interventions are needed based on initial evaluation, and to lessen support as language acquisition appears to become normalized, in the long run a better approach should involve continued diagnostic and support services.

Berninger and May (2011), for example, remark that some children referred for LDs around 4th grade appear to have had former diagnoses of SLIs in childhood. This suggests that their language performance did not in effect become normalized with Speech Therapy alone: while oral performance improved, some of the underlying problems with language may have remained unaddressed therapeutically (Berninger & May, 2011). A better approach would be to re-evaluate that child's performance in language based activities as well as in other domains on a regular basis, either when evidence of new developmental problems emerges, or as part of a continuing comprehensive developmental watch. In the case where OWL LDs or other LDs emerge later in the elementary years in a child who has an SLI, a Speech Pathologist may need to

be involved directly in the strategies involved in reading remediation, rather than merely making a referral to a reading specialist (Westby, 2016).

Secondly, areas of weakness may need to be taken into consideration even when such weaknesses may not cross a certain impairment threshold. The evidence already there suggests that any variation in development, whether statistically significant or not, is likely to affect domains of development outside of speech and language, all of which may later translate into impairments of reading and writing acquisition or OWL (Berninger, 2015; Berninger, Richards, & Abbott, 2015). When a child earlier diagnosed with an SLI is identified to have an OWL or other learning disorder later in the elementary years, an intervention team should strive to have a child comprehensively re-evaluated developmentally, focusing on uncovering other sensory and developmental weaknesses, especially in cases where a child's previous history indicates an SLI that has been "outgrown".

As educators, we often think about language production and literacy acquisition in terms of specific language skills and associated areas of the brain. However, if language is skill dependent not just on auditory processing and on mechanical reproduction of speech, but is also related to other sensory inputs, it would pay us to look at the whole sensory profile of children when determining their needs for remedial services.

> "Just as musicians produce music using many different end organs – mouths vocalizing song or blowing air, fingers moving sequentially on strings or wooden or metal parts, arms sliding metal parts, or hands tapping drums with or without a stick of metal or ivory – students learn to orchestrate internal mental processes with different sensory and motor end organs for different academic tasks." (Berninger, 2015, pg. 70).

Evidence is mounting for this orchestra metaphor when it comes to learning processes when it comes to language learning and its associations with other sensory skills. Perhaps the clinical recommendation for children identified as having just SLIs, or just SPDs, or just an isolated development issue, should entail an opportunity for access to more than just a Speech and Language Pathologist in the classroom, especially when SLP interventions alone, or reading interventions alone, do not yield satisfactory results.

For example, if a child considered to be one or two standard deviations from the norm of language development is not responding to stand alone speech therapy, and that child has previously tested somewhat below the mean for gross or fine motor development in the past, it may be necessary to add some occupational or physical therapy to the intervention in order to support the student. Later on, the child's intervention team should revisit and re-evaluate both language performance and motor development. If positive gains are occurring linguistically three months after such additional intervention has begun, such gains may suggest that the additional therapies are relevant parts of the intervention for that specific child.

Future Directions for Research

Educators in the area of language acquisition, both at the early childhood and early elementary levels may want to further investigate the connection between SLIs, SPDs, and neurodevelopmental motor problems as laid out above. Based on the preceding literature, one may hypothesize that children who fall into more than one of these categories might benefit from sensory training as administered by certified Occupational Therapists. An occupational therapist works with a patient who exhibits difficulties in executing gross and fine motor skills required in daily living tasks in order for them to learn how to execute those movements. It might pay to

look into whether occupational therapy may also have an effect on strengthening the procedural memory processes that are associated with those movement tasks.

Such interventions should be administered in a study setting, to identify possible correlations between receiving expanded services and language gains. In such a setting, both an experimental group and a control group would continue receiving Speech and Language therapy during such a study. If that kind of study confirms the hypothesis that there are stronger links between language, sensory sensitivities, and motor skills than we previously posited in education, such results may suggest the need for further research.

One line of inquiry should focus on providing children who display particular sensory sensitivities (auditory, vestibular, prioceptive[2], and the like) in children with SLI, and continuing to monitor their linguistic and cognitive performance over time, as compared with a group of children similarly affected who are only receiving speech therapy services, as well as an age matched control group of neurotypical children. The efficacy of added intervention can further be tested by expanding it to a new group of children selected using similar criteria, and continuing said additional therapies over time. During therapy, of course, researchers would be collecting data through a quantitative-qualitative study, the first part of which replicates prior findings, while a latter phase follows participants longitudinally using a variety of both qualitative (observation, interview, and the like) and quantitative data (by looking at their achievement using standardized testing already administered in their school settings, compared to other control groups).

[2] Prioception is the ability to make intuitive sense of a sequence of movements. Difficulties in prioception can occur in tandem with vestibular insecurity or without.

A different line of inquiry may be to replicate the sort of study proposed above using new participants, but adding a component of research where variance is not only sought in terms of differential scores, but also by investigating the neural patterns of the participants measured using fMRI. While incorporating fMRI into studies of language performance can at times be an expensive proposition, and as such fMRI is seldom used in diagnostic contexts, once data the likes of which we described above suggest that the basis of impairment in children with language disorders are in fact neurological, incorporating fRMI measures becomes a justifiable expense as a way to further pinpoint any differences specifically tied with the treatment mode.

Such lines of inquiry would lead to further understanding of what it takes to exploit brain plasticity in order to minimize later academic problems for children with developmental language disorders. As this paper tried to argue, it is becoming more and more likely that said inquiries are necessary to help many children learn.

References

Adi-Japha, E., & Abu-Asba, H. (2014). Learning, Forgetting, and Relearning: Skill Learning in Children with Language Impairment. *American Journal of Speech-Language Pathology*, *23*(4), 696–707 12p. https://doi.org/10.1044/2014_AJSLP-13-0031

Ayres, A. J. (1972). *Sensory integration and learning disorders,*. Los Angeles, Calif.: Los Angeles, Calif., Western Psychological Services.

Bassett, D. S., & Gazzaniga, M. S. (2011). Understanding complexity in the human brain. *Trends in Cognitive Sciences*, *15*(5), 200. https://doi.org/10.1016/j.tics.2011.03.006

Berninger, V. W. (2015). *Interdisciplinary frameworks for schools: Best professional practices for serving the needs of all students.* American Psychological Association.

Berninger, V. W., & May, M. O. (2011). Evidence-Based Diagnosis and Treatment for Specific Learning Disabilities Involving Impairments in Written and/or Oral Language. *Journal of Learning Disabilities*, *44*(2), 167–183. https://doi.org/10.1177/0022219410391189

Berninger, V. W., Richards, T. L., & Abbott, R. D. (2015). Differential Diagnosis of Dysgraphia, Dyslexia, and OWL LD: Behavioral and Neuroimaging Evidence, *28*(8), 1119–1153. https://doi.org/10.1007/s11145-015-9565-0

Bishop, D. V. M., Nation, K., & Patterson, K. (2014). When words fail us: insights into language processing from developmental and acquired disorders. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *369*(1634), 20120403. https://doi.org/10.1098/rstb.2012.0403

Bishop, D. V. M., & Snowling, M. J. (2004). Developmental dyslexia and specific language impairment: same or different?(Author Abstract). *Psychological Bulletin*, *130*(6), 858.

Bracken, B. A., & Nagle, R. J. (Richard J. (2007). *Psychoeducational assessment of preschool children*. Mahwah, N.J.: Mahwah, N.J. : Lawrence Erlbaum Associates.

Brumbach, A. C. D., & Goffman, L. (2014). Interaction of language processing and motor skill in children with specific language impairment.(Research Article)(Report), *57*(1), 158.

Catts, H. W., Adlof, S. M., Hogan, T. P., & Weismer, S. E. (2005). Are Specific Language Impairment and Dyslexia Distinct Disorders? *Journal of Speech, Language, and Hearing Research*, *48*(6), 1378–1396. https://doi.org/10.1044/1092-4388(2005/096)

Catts, H. W., Bridges, M. S., Little, T. D., & Tomblin, J. B. (2008). Reading Achievement Growth in Children with Language Impairments. *Journal of Speech, Language, and Hearing Research*, *51*(6), 1569–1579. https://doi.org/10.1044/1092-4388(2008/07-0259)

Catts, H. W., Fey, M. E., Tomblin, J. B., & Zhang, X. (2002). A Longitudinal Investigation of Reading Outcomes in Children with Language Impairments. *Journal of Speech, Language, and Hearing Research*, *45*(6), 1142–57.

Chang, Y.-S., Owen, J. P., Desai, S. S., Hill, S. S., Arnett, A. B., Harris, J., … Mukherjee, P. (2014). Autism and Sensory Processing Disorders: Shared White Matter Disruption in Sensory Pathways but Divergent Connectivity in Social-Emotional Pathways.(Research Article), *9*(7).

Cumming, R., Wilson, A., & Goswami, U. (2015). Basic auditory processing and sensitivity to prosodic structure in children with specific language impairments: a new look at a perceptual hypothesis. *Frontiers in Psychology*, *6*, 972. https://doi.org/10.3389/fpsyg.2015.00972

Cumming, R., Wilson, A., Leong, V., Colling, L. J., & Goswami, U. (2015). Awareness of Rhythm Patterns in Speech and Music in Children with Specific Language Impairments, *9*, 672. https://doi.org/10.3389/fnhum.2015.00672

Desmottes, L., Meulemans, T., & Maillart, C. (2016). Later learning stages in procedural memory are impaired in children with Specific Language Impairment. *Research in Developmental Disabilities*, *48*, 53–68. https://doi.org/10.1016/j.ridd.2015.10.010

Ferguson, M. A., Hall, R. L., Riley, A., & Moore, D. R. (2011). Communication, Listening, Cognitive and Speech Perception Skills in Children with Auditory Processing Disorder (APD) or Specific Language Impairment (SLI). *Journal of Speech, Language, and Hearing Research*, *54*(1), 211–227. https://doi.org/10.1044/1092-4388(2010/09-0167)

Fogle, P. T. (2008). *Foundations of communication sciences & disorders*. Clifton Park, NY: Clifton Park, NY : Thomson Delmar Learning.

Fox, S. E., Levitt, P., & Nelson, C. A., III. (2010). How the Timing and Quality of Early Experiences Influence the Development of Brain Architecture. *Early Childhood*, *81*(1), 28–40. https://doi.org/10.1111/j.1467-8624.2009.01380.x

Franco, E. S., & Panhoca, I. (2008). Vestibular function in children underperforming at school. *Brazilian Journal of Otorhinolaryngology*, *74*(6), 815.

Gupta, P. (2011). Word learning as the confluence of memory mechanisms: Computational and neural evidence. In M. Faust (Ed.), *The handbook of the neuropsychology of language* (Vol. 1, pp. 146–163). Chicester: Chicester : Wiley.

Hulme, C., & Snowling, M. J. (2014). The interface between spoken and written language: developmental disorders. *Philosophical Transactions of the Royal Society of London.*

Series B, Biological Sciences, *369*(1634), 20120395. https://doi.org/10.1098/rstb.2012.0395

Justice, L., Logan, J., Kaderavek, J., Schmitt, M. B., Tompkins, V., & Bartlett, C. (2015). Empirically Based Profiles of the Early Literacy Skills of Children with Language Impairment in Early Childhood Special Education, *48*(5), 482–494. https://doi.org/10.1177/0022219413510179

Kim, J., Kim, D. I., Kim, Y. W., Park, C.-I., Park, E. S., Kim, H.-H., & Lee, S.-K. (2006). Diffusion-tensor magnetic resonance imaging in children with language impairment. *NeuroReport*, *17*(12), 1279–1282. https://doi.org/10.1097/01.wnr.0000230516.86090.67

Kruger, R. J., Kruger, J. J., Hugo, R., & Campbell, N. G. (2001). Relationship Patterns between Central Auditory Processing Disorders and Language Disorders, Learning Disabilities, and Sensory Integration Dysfunction. *Communication Disorders Quarterly*, *22*(2), 87–98.

Leonard, H. C., & Hill, E. L. (2014). Review: The impact of motor development on typical and atypical social cognition and language: a systematic review. *Child and Adolescent Mental Health*, *19*(3), 163–170. https://doi.org/10.1111/camh.12055

Leonard, Deevy, P., Fey, M. E., & Bredin-Oja, S. L. (2013). Sentence Comprehension in Specific Language Impairment: A Task Designed to Distinguish between Cognitive Capacity and Syntactic Complexity. *Journal of Speech, Language, and Hearing Research*, *56*(2), 577–589. https://doi.org/10.1044/1092-4388(2012/11-0254)

Lum, J., Conti-Ramsden, G., Page, D., & Ullman, M. (2012). Working, declarative and procedural memory in specific language impairment. *Cortex*, *48*(9), 1138–1154.

Mashburn, A. J., & Myers, S. S. (2010). Advancing research on children with speech-language impairment: an introduction to the early childhood longitudinal study--kindergarten

Cohort.(Clinical Forum)(Report). *Language, Speech, & Hearing Services in Schools*, *41*, 61.

Mayes, A. K., Reilly, S., & Morgan, A. T. (2015). Neural correlates of childhood language disorder: a systematic review. *Developmental Medicine & Child Neurology*, *57*(8), 706–717. https://doi.org/10.1111/dmcn.12714

Mcclelland, M., Morrison, F., & Holmes, D. (2000). Children at risk for early academic problems: The role of learning-related social skills. *Early Childhood Res. Q.*, *15*(3), 307–329.

Messer, D. J., & Dockrell, J. (2001). *Children's language and communication difficulties : understanding, identification and intervention*. London: London : Continuum.

Mora, J., & Kashman, N. (2002). *An OT and SLP team approach : sensory and communication strategies that WORK!* Las Vegas, NV: Las Vegas, NV : Sensory Resources.

Morgan, P. L., Farkas, G., & Wu, Q. (2011). Kindergarten Children's Growth Trajectories in Reading and Mathematics, *44*(5), 472–488. https://doi.org/10.1177/0022219411414010

Nittrouer, S., & Pennington, B. (2010). New Approaches to the Study of Childhood Language Disorders. *Current Directions in Psychological Science*, *19*(5), 308.

Owen, J. P., Marco, E. J., Desai, S., Fourie, E., Harris, J., Hill, S. S., … Mukherjee, P. (2013). Abnormal white matter microstructure in children with sensory processing disorders. *NeuroImage. Clinical*, *2*, 844. https://doi.org/10.1016/j.nicl.2013.06.009

Paulson, L. H., Kelly, K. L., Jepson, S., van den Pol, R., Ashmore, R., Farrier, M., & Guilfoyle, S. (2004). The Effects of an Early Reading Curriculum on Language and Literacy Development of Head Start Children, *18*(3), 169.

Pennington, B. F., & Bishop, D. V. M. (2009). Relations Among Speech, Language, and Reading Disorders. *Annu. Rev. Psychol.*, *60*, 283–306. https://doi.org/10.1146/annurev.psych.60.110707.163548

Rechetnikov, R. P., & Maitra, K. (2009). Motor impairments in children associated with impairments of speech or language: a meta-analytic review of research literature.(Report). *AJOT: American Journal of Occupational Therapy*, *63*(3), 255.

Rice, M. L., & Hoffman, L. (2015). Predicting vocabulary growth in children with and without specific Language impairment: A longitudinal study from 2. *Journal of Speech, Language, and Hearing Research*, *58*(2), 345–359. https://doi.org/10.1044/2015_JSLHR-L-14-0150

Rindermann, H., & Baumeister, A. E. E. (2015). Parents' SES vs. parental educational behavior and children's development: A reanalysis of the Hart and Risley study. *Learning and Individual Differences*, *37*, 133–138. https://doi.org/10.1016/j.lindif.2014.12.005

Saletta, M., Gladfelter, A., Vuolo, J., & Goffman, L. (2015). Interaction of motor and language factors in the development of speech production. In R. H. Bahr & E. R. Silliman (Eds.), *Routledge handbook of communication disorders* (pp. 381–391). Lomdon: Routledge.

Skibbe, L. E., Grimm, K. J., Stanton-Chapman, T. L., Justice, L. M., Pence, K. L., & Bowles, R. P. (2008). Reading Trajectories of Children with Language Difficulties from Preschool through Fifth Grade. *Language, Speech, and Hearing Services in Schools*, *39*(4), 475–486. https://doi.org/10.1044/0161-1461(2008/07-0016)

Ullman, M. T., & Pierpont, E. I. (2005). Specific language impairment is not specific to language: the procedural deficit hypothesis, *41*(3), 399.

Van Dun, K., Manto, M., & Mariën, P. (2016). The language of the cerebellum, 1–21. https://doi.org/10.1080/02687038.2015.1132297

Vissers, C., Koolen, S., Hermans, D., Scheper, A., & Knoors, H. (2015). Executive functioning in preschoolers with specific language impairment. *Frontiers in Psychology*, *6*, 1574. https://doi.org/10.3389/fpsyg.2015.01574

Vydrova, R., Komarek, V., Sanda, J., Sterbova, K., Jahodova, A., Maulisova, A., … Kyncl, M. (2015). Structural alterations of the language connectome in children with specific language impairment. *Brain and Language*, *151*, 35. https://doi.org/10.1016/j.bandl.2015.10.003

Westby, C. (2016). Early Literacy Profiles in Children With Language Impairment, *27*(4), 8–11. https://doi.org/10.1177/1048395015623963b

Williams, S. C. P. (2013). Epigenetics, *110*(9), 3209. https://doi.org/10.1073/pnas.1302488110