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Links Between Specific Language Impairment, Motor Development, and Literacy Acquisition in Children

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Abstract: This study set out to explore the links between specific language impairment (SLI), motor development, and literacy acquisition in children. We focused on motor those motor deficits that are most common in children with SLI; furthermore, we investigated whether SLI can be caused by persisting primary reflexes or if they can make the symptoms of SLI worse. After that we tried to find out if it is possible to predict SLI already in small children by an early development assessment and if a specific movement intervention programme would also be useful to help children with SLI because children with developmental speech/language impairments are at higher risk of reading disability than their intact peers with no history of speech/language impairment (Schuele, 2004). We still do not fully understand the causes and biological basis of SLI; however, on the evidence of the sources studied, a significant relationship between motor impairment and speech/language impairments in children was found. Typical difficulties lie in the areas of balance, general static coordination, and general dynamic coordination. This developmental delay may be related to the persistence of primary reflexes or can be caused by a cerebellar deficit. Several early developmental assessments are available, but they do not comprehensively test both motor development and language skills. Specific movement intervention programmes for children with SLI and other developmental challenges have already been developed, but we lack fundamental research (only a few case studies on this topic are available) which shows the success rate for children with SLI. Further research should be conducted to identify children who may need special interventions even before they receive the SLI diagnosis, and to search for approaches which can help to mitigate the impairment.

Keywords: Specific language impairment (SLI); motor development; literacy acquisition; persisting primary reflexes

Definition of specific language impairment

According to the DSM-IV-TR criteria (Diagnostic and statistical manual of mental disorders published by the American psychiatric association, 2000), specific language impairment (SLI) may be diagnosed when language abilities are significantly below age expectations but where non-linguistic developmental abilities are within age expectations. That means there must be a marked discrepancy between language scores and nonverbal IQ on standardised tests. In addition, the language difficulties must interfere with academic achievement or occupational achievement or social communication. The language impairment is not secondary to conditions such as hearing loss, developmental delay, a neurological insult, or environmental deprivation.

In the foreign literature, however, we can also find other terms for developmental language disorders. We can distinguish three groups in the terminology.

In the first group, the focus is on the disorder. In the Netherlands and Belgium these terms are used: specifieke taalontwikkelingsstoornis, primaire taalontwikkelingsstoornis, aangeboren taalontwikkelingsstoornis, taalontwikkelingsstoornis, and spraak- en taalontwikkelingsstoornis. In the UK and the USA the terms (specific) developmental language disorder or language acquisition disorder are used.

In the second group, we see the word dysphasia. In Dutch the terms that are used are ontwikkelings dysfasie or dysfatische ontwikkeling, in German entwicklungsdysphasie, in French la dysphasia, in English developmental dysphasia, and in Czech vývojová dysfázie.

The third group focuses on the impairment without trying to explain the medical origin of the problem. In Dutch, we find the term ernstige spraak/taalmoeilijkheden, in English specific language impairment (SLI), developmental language impairment, or primary language impairment and recently we have also been able to find the term procedural language impairment.

The reason why so many different terms are used for what is essentially the same problem is that the authors want to focus on a part of the problem. For a long time the term developmental dysphasia was frequently used. This term came from the medical world and points to the neurological origin of the language impairment. Later, however, some authors from the non-medical environment determined that the term developmental dysphasia is not accurate, because children with a language impairment do not have a demonstrable brain injury. Moreover, it would be too easy to confuse it with the term "child aphasia", which is caused by brain damage (Zink & Breuls, 2012). Therefore, in the '90s some authors in England and the USA started to use the terms "Specific Developmental Language Disorder" and "Specific Language Impairment". The term "disorder" points out that it is not just a delay in language development, but it also points out to root cause of the language problem . The term "impairment" shows that there is a problem with language development, but does not call this problem a disorder and does not try to seek the origin of the problem. This group can include children with a language developmental delay, out of which they can grow, as well as children with a persistent language impairment. One of the most significant comments on the term SLI is that the "S" (specific) in SLI would exclude the possibility that a child can have other developmental problems as well. It is true that the definition of SLI states that the impairment is not caused by other developmental problems such as a hearing impairment, socio-emotional problems, etc., but that does not exclude the possibility that the child faces other developmental challenges as well. This is probably the reason why the term "developmental dysphasia" is still firmly embedded in Europe. In this review study, however, I will use the term "SLI" because it is the most common one in English-language sources, but to provide the opportunity to locate as many studies as possible, I also searched for and used studies which use the other commonly used terms mentioned above.

Specific language impairment, motor development, and literacy acquisition

Categorical diagnosis is an integral part of everyday clinical and research practice. We are so insistent on the distinction between disorder and not disorder (normalcy) that clinics and clinicians become more and more specialized and cater to the needs of children with autism spectrum disorder/ASD only, attention-deficit/hyperactivity disorder/ADHD only, language disorder only, reactive attachment disorder/RAD only, or tourette syndrome only. This has led to a situation in which the typical clinical diffuseness of disorder has come to be underestimated (Gillberg, 2013).

A number of studies have shown that SLI is not "specific" and that comorbidities are common (Dyck & Piek 2010; Gillberg, 2010; Hill, 1998; Kaplan et al., 1998; Manor, Shalev, Joseph, & Gross-Tsur, 2001). In particular, there is growing evidence that many children with SLI have some level of motor difficulty (Hill, 2001; Webster et al, 2006). Hill (2001) states that children with SLI generally experience a broader range of difficulties, of which motor incoordination is one. Hill produced a list of studies that investigated non-linguistic abilities in children with SLI. The majority of studies reported have focused on fine motor tasks, and particularly on the time taken to complete the task as the variable of interest. Typically, children with SLI are reported to be impaired relative to their normally developing peers, although on some repetitive finger-tapping tasks their performance was unimpaired, as it was on the task of placing crosses in boxes. In contrast, where performance accuracy on a fine motor task has been assessed, children with SLI tend to be unimpaired in comparison with their normally developing peers (Johnston et al., 1981; Preis et al., 1997), with the exception of performance on the Ayres motor accuracy test revised. Jenkins and Lohr (1964) point out that for gross motor skills, the typical difficulties lie in the areas of balance, general static coordination, and general dynamic coordination. Powel and Bishop (1992) agree with this result, and state that children with SLI have problems with tasks such as balance, throw-clap-catch, and ball rolling-stick (with the preferred hand). However, ball rolling-stick with the non-preferred hand and ball rolling-foot are unimpaired. Other researchers find different outcomes. Johnston et al. (1981) find that children with SLI have, in the gross motor area, problems with hopping, but are unimpaired in tasks such as line walking, unipedal stand, and bipedal stand (which are balance tasks). Finlay and McPhillips (2013) used the Movement ABC-2 test in their research to compare the motor abilities of children with SLI to age-matched children with typical language development and age-matched children who had not been clinically identified as having SLI but exhibited low levels of language abilities. The objective of their study was to determine whether children with SLI experienced greater motor difficulties than children without an SLI diagnosis. The outcome was that children with SLI scored significantly lower on all three composites ("manual dexterity", "aiming and catching", and "balance") of the MABC-2 test when the age-matched low language and typical (intact) groups were compared.

Estil et al. (2003) also tried to identify children (of the ages of 7–8 years, 9–10 years, and 11–12 years) with motor impairment problems by using the Movement ABC test; the results of the total scores on this test showed a significant difference in overall motor performance between the two groups (a language-impaired group and control group), which confirm the findings of those studies that have shown a significant association between language and motor impairment. But, they add, the coincidence of language and motor impairments is characteristic for only a limited sample of language-impaired children and so caution should be observed in making generalisations on the basis of group data without a more careful investigation of individual language/motor profiles. Where motor and language impairment occur together, they argue, the motor deficiencies may not be general but restricted to a relatively small number of fine motor skills. That is why Hill (2001) proposed that children with SLI who experience motor difficulties are maybe a subset of those with SLI. The first group of children with SLI who were identified as experiencing significant motor difficulties on the Movement ABC test (Clumsy SLI) and the second group are those, who according to the MABC test, are developing in a motorically normal fashion (non-Clumsy SLI). DiDonato, Brumbach and

Goffman (2014) are not surprised that children with SLI are heterogeneous, and only some showed an overt motor deficit. According to DiDonato Brumbach and Goffman, in neuroanatomical studies we find the reason why children with SLI show co-occurring deficits in the language and motor domains. Broca's area, which is involved in syntactic language functions, also coordinates the mirror neuron system, which supports the notion of a specific relationship between syntactic and motor abilities. Jäncke, Siegenthaler, Preis, and Steinmetz (2007) showed that children with developmental language disorders had a reduced volume of white matter in the motor areas of the left hemisphere and also corresponding behavioural deficits in a complex manual coordination task. Estil et al. (2003) also propose two hypotheses on the neuro-psychological level: the cerebellar deficit hypothesis and the inter-hemispheric deficit hypothesis.

The main implication of the automaticity/cerebellar deficit hypothesis is the presence of motor deficits in dyslexic children. Phonological dyslexics is a deficit closely related to phonological language impairment (Plaza, 1997). Using clinical tests of cerebellar function, Plaza found dyslexics to be impaired in terms of balance and a number of fine motor tasks associated with cerebellar function. That language-/motor-impaired children exhibit similar deficiencies in motor skills to those of dyslexic persons suggests that there might be a common mechanism that mediates all these deficiencies (Estil, 2003). Some of the cerebellar tests involve the speed of manual movement (tracking), bimanual co-ordination (for example rapid alternating movements), and static balance, which are similar categories of motor skill to those that appeared to be critical to language and motor impairment. According to Richard Ivry and his colleagues (Ivry & Diener, 1991; Ivry & Keele, 1989; Keele et al., 1985), bimanual movements may be dependent on the temporal coupling of signals within the cerebellum. Each half of the cerebellum has been shown to regulate the temporal aspects of movements on the ipsi lateral side independently. This suggestion is based on findings from repetitive finger-tapping tests on cerebellar patients. The significant differences between the groups on the task of drawing (tracking) can also be accommodated in the cerebellar explanation. A study using positron emission tomography (PET) (Jueptner et al., 1996) showed that the cerebellum, and to some extent also the basal ganglia, was activated during a visually guided tracking task, where the participants had to track a series of lines with a mouse pointer on the screen. Additionally, in a study of cerebral blood flow Grafton et al. (1992) found that tracking a moving target with the index finger activated the primary motor cortex, dorsal parietal cortex, precuneate cortex, supplementary motor area, and ipsi lateral anterior cerebellum. Diamond (2000; Estil, 2003) probes deeper into the causal network in her concept of a neuroanatomical circuit deficiency between the prefrontal cortex and the cerebellum. She argues that motor and cognitive development are much more interrelated than was previously appreciated, and points to the fact that fine motor control, bimanual co-ordination, and visuomotor skills, together with certain cognitive operations, are not fully developed until adolescence, which may be seen in relation to the phylogenetic development of the neocerebellum and the prefrontal cortex, which proceed in parallel (Estil, 2003). Raberger and Wimmer (2003) attempted to examine, within the cerebellar deficit hypothesis, the relationship of reading disability (RD) and attention deficit hyperactivity disorder (ADHD) with balancing problems. They found that a specific cerebellar dysfunction probably affects only the automatisation of such visual-verbal processes. Other cerebellar functions which are responsible for the automatisation of basic sensory-motor skills such as balancing may not be affected in dyslexic children but are in children with ADHD. Static balancing on one leg involves proprioceptive information from the foot, which is processed in the right hemisphere, and so it is possible that balancing problems in some children with dyslexia and SLI can be caused by right hemispheric insufficiency with or without a dysfunctional corpus callosum. The study of Meister et al. (2003) supports the theory of the existence of a strong evolutionary link between the cortical hand area and the development of language. This hypothesis emerges from the existence of mirror neurons that are active both during observation and the execution of tasks such as grasping objects. These neurons are located in an area of the cortex of macaque monkeys that seems to correspond to Broca's area in the human cortex. The proponents of this theory argue that such an observation/execution-matching system can bridge the gap between action and communication about action and thus forms the neural basis of the development of language. According to this theory, there should be phylogenetically old links between motor hand and language areas, and these would be responsible for the effect they found. Several findings emphasise the assumption of a functional coupling between speech and the hand motor area of the language-dominant hemisphere. One obvious link between these two regions is the fact that involuntary gestures are often performed during speech. Children with speech/language impairments are at great risk of reading disabilities. Schuele (2004) concludes that "proficient reading requires highly integrated skills across word decoding and comprehension that draw on basic language knowledge (semantics, syntax, and phonology). Children with language impairments have problems in decoding and comprehension. Clearly, expressive and receptive oral language deficits are associated with the reading disabilities of young children who have developmental language impairments, but related deficits in phonological awareness are a factor as well."

Specific language impairment, motor development, and primary reflexes

Another hypothesis is that the underlying developmental delay of children with SLI and dyslexia is related to the persistence of primary reflexes. Primary reflexes emerge in utero and their appearance at this early stage of development suggests that they may play an important role in determining the functioning of the central nervous system (Illingworth, 1987). The primary reflexes are critical for the survival of the newborn, ensuring that the baby can breathe and feed (for example, the Moro reflex or infant suck and rooting reflexes). As the nervous system develops, however, they are inhibited or transformed and the persistence of primary reflexes beyond their normal timespan (12 months) interferes with subsequent development and indicates neurological impairment (Holt, 1994). Severe persistence of primary reflexes indicates predominantly intractable organic problems as in cerebral palsy (Bobath & Bobath, 1988), while milder persistence is associated with less severe disorders, including learning disabilities (Morrison, 1985). Certain disorders developed during early stages of life may lead to balance deficits as a consequence of higher-level dysfunctions of the central nervous system. The dysfunctions result in developmental deficits in the coordination of certain neurophysiological and mental functions. One of the particularly important postnatal developmental stages is the disappearance of primary (or primitive) reflexes. The primary reflexes represent specific forms of innate behavioural movement patterns which are replaced with higher motor and cognitive functions during postnatal development. These primitive reflexes may present a form of soft neurological signs if they occur in later stages of ontogenesis (Konicarová, 2013). Primary reflexes help the brain to learn how to control the body – visuomotor skills, processing visual and auditory information, balancing, coordination, gross and fine motor skills, etc. (O'Hara, 2009). It has been shown that some children with reading difficulties have underlying developmental delays and that this may be related to the persistence of primary reflexes (McPhillips & Sheehy, 2004). The findings of McPhillips suggest that for many children in mainstream schooling, the attainment of core educational skills may be affected by the persistence of this brainstem-mediated reflex system that should have been inhibited in the first year after birth, because, as shown earlier in this review study, phonological dyslexics is a deficit closely related to phonological language impairment, and so it is possible that primary reflexes have an impact on SLI as well. That is also proved by the case studies that I performed within my master's thesis (Volemanová, 2016), where a child with SLI had persisting primary reflexes and after inhibiting them, his problems with gross and fine (including oromotor) motor skills got better, as did his concentration. Also in a study evaluating the effectiveness of a specific movement intervention programme with children aged 8-11 years old with reading problems, it was found that it was possible to reduce the level of primary reflex interference, in particular asymmetrical tonic neck reflex, at this late stage of development and that this led to very significant progress in reading and writing skills (McPhillips, Hepper, & Mulhern, 2000). There are very close links between the inhibition of primary reflexes and the attainment of gross-motor milestones in young children (Capute et al., 1978; McPhillips, Hepper, & Mulhern, 2000). In children with SLI, the following primary reflexes seem to be important: the moro reflex, tonic labyrinth reflex (TLR), and asymmetrical tonic neck reflex (McPhillips, Hepper, & Mulhern, 2000; Volemanová, 2016).

Moro reflex

The moro reflex is an infantile reflex normally present in all infants (new-borns) up to three or four months of age as a response to a sudden loss of support, when the infant feels as if it is falling. If the reflex is absent, reduced, or hyperactive during the first three months of life, this may indicate various pathological conditions, mainly of cerebral origin (Zafeiriou, 2004). Children with a persisting moro reflex often have problems with balance, which is logical because vestibular stimulation seems to play a crucial role in triggering the moro reflex (Hanabusa, 1975 in Rousseaua et al. 2017). This reflex is controlled by the fear system (the primary emotional systems which control nuclei are in the subcortical structures of the brain), which can be activated from birth by unconditioned stimuli such as sudden noise. This also explains why Konicarová (2013) found a link between balance deficits, primary reflex persistence, and ADHD symptoms. Konicarová (2013) concludes that: "According to brain imaging studies these balance deficits are likely linked to prefrontal cortex deficits that influence attention and executive functions. These deficits may have a cerebellar origin and ADHD children in many cases exhibit atrophy in certain cerebellar parts associated with balance control. The deficits may be directly linked to inhibitory deficits and cause balance and motor dysfunctions. As a result of inhibitory deficits related to disturbed balance and motor functions observed with ADHD, the primitive reflexes that were not sufficiently suppressed in later stages of development may most likely persist. According to certain findings similar deficits in the primitive reflex suppression have also been observed in children with dyslexia." In this respect ADHD symptoms may present a compensatory process related to the interference of more primitive neural mechanisms with higher levels of brain functions related to coordination and balancing mechanisms as a result of insufficiently developed cognitive and motor integration. The consequence of this disintegration in the developmental hierarchy of the central nervous system may be demonstrations of ADHD symptoms in response to various stimuli caused by the conflict between higher and lower levels of cognitive and motor functions within brain processing, which may cause the disintegration of mental functions.

Tonic labyrinth reflex (TLR)

There are two labyrinth reflexes that are triggered by the position of the head in relation to gravity – the prone and supine tonic labyrinth reflex. The TLR should be inhibited till the end of the fourth month after birth. When we lean the head of the child forward, all the limbs will flex (arms and legs), and when we tilt the head backwards while the child is lying on its back, the reflex causes the back to stiffen and even arch backwards, the legs to straighten, stiffen, and push together, the toes to point, the arms to extend at the elbows and wrists, and the hands to form fists or the fingers to curl. The purpose of this reflex is to develop the muscles used in flexion, which balance the extensor muscles that are developed when the child is placed on its back. If this reflex persists, the child will have problems with movements against the pull of gravity. This reflex persists if the child does not learn to hold its head properly at the age of three months. The normal motor development of the child goes in the craniocaudal direction, but if the TLR persists, the child will not learn to hold its head in the optimal position, which affects later balance. Balance mechanisms regulate other sensory organs and muscle groups, for example the position of the eye in the orbit (Lorenthe, 1932). At later ages, we see poor body posture, with the head protruding forward in relation to the shoulder joint, and as the body follows where the head goes, the shoulders will also hunch forward with it. In school, when it has to look down at a book, the child will have problems sitting straight. When the head is in a protruding position, the jaws will not be in a stable position for chewing and talking and low tongue posture can occur. The tongue too, at central level, involves several complex movements globally ruled by the central nervous system (CNS), particularly swallowing and mastication, but the tongue position also affects lower limb performance (Vico et al., 2014).

Asymmetrical tonic neck reflex (ATNR)

The most frequently observed persisting primary reflex in infants with neurological lesions is the ATNR (McPhillips, 2004). This reflex is elicited by a sideways turning of the head and the response consists of extension of the arm and leg on the side to which the head turns and flexion of the opposing limbs (Illingworth, 1987). The arm stretches out towards the direction that the eyes are pointing in and as the hand encounters objects, the foundations of early hand-eye co-ordination are laid (Holt, 1994). If the ATNR persists beyond the normal timespan, the child is likely to experience fine and gross motor control problems. The ATNR initially stimulates asymmetrical visual and motor exploration of the young child's environment but as it is inhibited symmetrical movements become possible with, for example, objects being brought to the midline and passed from one side to the other. The transference of objects across the midline is a significant motor milestone usually achieved between six and eight months after birth (Holt, 1994). The persistence of the ATNR will also disrupt the emergence of gross motor abilities such as rolling, creeping, crawling, riding a bicycle, and catching or kicking a ball. At school, when a child with a persistent ATNR looks towards the hand that is holding a pencil in order to write, the ATNR will cause an extensor tonus in that arm. This presents problems for the child in developing a fine flexor, tripod grip or maintaining a flexed elbow when writing or drawing. The child may have to employ excessive tension and effort and this leads to muscular fatigue in the writing arm and poor motor control. Indeed, there are very close links between the inhibition of primary reflexes and the attainment of gross motor milestones in young children (Capute et al., 1978; Volemanová, 2014). When a child climbs, it receives proprioceptive information from its movements, which are repeated again and again with minimal differences. Coordinated movements in climbing promote better differentiation of movements. Climbing improves the coordination of movements and strengthens the deep stabilisation system (which is a functional unit of muscles affecting the stability of the hull in the sagittal plane). It is also noted that the climbing phase stimulates myelination in the CNS (especially the corpus callosum) and improves the eye movements and hand-eye coordination (Volemanová, 2016). In this matter, the problems a persisting ATNR can cause are similar to the cerebellar deficit hypothesis and intra-/inter-hemispheric deficit explained before. McPhillips (2004) investigated the prevalence of persisting primary reflexes in the ordinary primary school population and how this is related to other cognitive and social factors. In the results of the research he summarises the effect of the ATNR on movement, verbal IQ, movement, and sex differences and movement and social disadvantage:

- ATNR and Movement ABC: the bivariate correlation coefficient between the persistence of the ATNR and motor difficulties (as assessed by the Movement ABC) indicated that there was a moderately significant correlation. This suggests that children with a persisting ATNR are also at risk of having motor difficulties (and vice versa);
- ATNR, Movement ABC, and verbal IQ: the bivariate correlation coefficient between verbal IQ and the persistence of the ATNR was moderately significant, while the correlation between verbal IQ and motor difficulties was just significant. This suggests that hi-

gher levels of verbal IQ are associated with lower levels of the ATNR and with higher levels of motor skills;

- ATNR, Movement ABC, and sex difference: there was no evidence of a significant relationship between Movement ABC scores and the sex of the child, while the persistence of the ATNR and sex of the child were found to be almost significantly related. These analyses suggest that the persistence of the ATNR is possibly related to the sex of the child, with boys more at risk than girls, while motor difficulties as measured by the Movement ABC test seem to be very evenly distributed between the sexes;
- ATNR persistence, Movement ABC, and social disadvantage: there is little evidence to suggest that children with high levels of persistence of the ATNR come predominantly from socially deprived backgrounds. The persistence of the ATNR seems to be unrelated to social background. Motor difficulties also seem to be unrelated to social background.

This suggests that the persistence of the ATNR plays a role, direct or indirect, in delaying the reading progress of a significant number of children attending ordinary primary schools (McPhillips, 2004). McPhillips concluded: "It would appear that a persistent ATNR may be a particular problem for many dyslexic children but it is not a defining characteristic of dyslexia and it is important to stress that the phenomenon of persistent primary reflexes and their association with reading difficulties does not constitute a coherent theory of reading development. It may be more appropriate to construe the persistence of primary reflexes as a developmental 'risk factor' that in conjunction with other factors may impact on specific aspects of development (including cognitive development). In other words, persistent primary reflexes cannot adequately explain the emergence of reading difficulties but they may indicate children at risk of reading difficulties."

Relations between motor developmental and communicative milestones

Infants' advances in locomotion are related to advances in communicative development. LeBarton and Iverson (2016) investigated whether motor development was also related to the emergence of both verbal and nonverbal communicative milestones with some specificity: sitting development related to both verbal and nonverbal communication milestones, and prone development related to nonverbal communication milestones. Improvements in sitting relate to advances in consonant-vowel production as a result of the anatomical consequences of the sitting posture. Increasing stability in sitting demonstrates that the infant possesses the trunk control necessary to stabilise sitting while extending the arm. This ability potentially broadens the infant's opportunities to hold objects and extend them in the direction of the interlocutor to "show" the object to others in a manner that may support coordination with social behaviours (e.g. eye contact with the interlocutor). In other words, advances in sitting and prone development may have a far-reaching influence, impacting on development both within and beyond the motor domain. This far-reaching influence may extend beyond the immediate context through these cascading consequences. Thus, for example, motor development may shape the learning environment in such a way that advances in motor skill bring novel experiences with them (Iverson, 2010). For instance, increasing stability and flexibility in sitting support object manipulation and exploration activity by expanding the manual movement repertoire as well as supporting the coordination of looking while exploring. In addition to supporting the development of manual exploration, gross motor development in infancy supports interaction with people. Meaningful interactions with others may serve as an addition mechanism through which gross motor achievements can support language development. For instance, the production of gestures elicits input from others that may support word learning. Caregivers often "translate" an infant's gestures (e.g. a caregiver may say "that's a ball" when the infant shows a ball to them), and such translations relate to the emergence of these words in the infant's spoken vocabulary (Goldin-Meadow et al., 2007). Thus, developments in gesture production – supported by advances in gross motor skills – may elicit these translations, which may in turn support word learning.

But is it therefore possible to predict SLI in small children by early developmental (motor) assessment? Preschool children also acquire a variety of motor skills which are important for their physical and academic development. Therefore, understanding the relationship between motor skills and speech/language skills at preschool age is important for early intervention. Motor skills in preschoolers were shown to predict later achievement in reading and maths and proved useful in identifying children at risk in terms of their school achievement. Grissmer et al. (2010), for example, found out that together, attention, fine motor skills, and general knowledge are much stronger overall predictors of later maths, reading, and science scores than early maths and reading scores alone. The comorbidity of motor and speech/language impairments in 363 preschool children aged five and six years was also investigated by Cheng et al. (2009). It was determined that the children presented no apparent impairments of the neurological, musculoskeletal, or cardiopulmonary systems or mental insufficiency. Three speech/language tests and a motor test (Movement assessment battery for children, or M-ABC) were administered to them. The results showed a significant correlation between the total score for the motor test and the total score for each of the speech and language tests. Regression analysis that controlled for IQ (C-TONI, the Chinese version of the Test of nonverbal Intelligence) further showed that the manual dexterity subtest, but not the ball skills or balance ones, of M-ABC was predictive of all the scores on the speech and language tests. Thus manual dexterity, in particular, seems to be an important clue for understanding the shared mechanism of motor and speech/language impairments. Cheng argues that this can be explained by a recent study (Meister et al., 2003) performed with transcranial magnetic stimulation (TMS). There they noted a strong correlation of the excitability of the hand motor area but not the leg motor area with speech events. It indicated a specific functional connection between the hand motor area and the cortical language network. These findings may explain why there were significant correlations of the manual dexterity subtests, but not the ball skill or balance ones, to all the speech/language scores. Meister et al. (2003) examined the excitability of the hand motor area and the leg motor area during reading aloud and during nonverbal oral movements using transcranial magnetic stimulation (TMS). During reading aloud, but not before or afterwards, excitability was increased in the hand motor area of the dominant hemisphere. This reading effect was found to be independent of the duration of the speech. No such effect could be found in the contralateral hemisphere. The excitability of the leg area of the motor cortex remained unchanged during reading aloud. The excitability during non-verbal oral movements was slightly increased in both hemispheres. The results may indicate a specific functional connection between the hand motor area and the cortical language network.

Woods (2014) also agrees that systematic developmental follow-up is important to reliably identify the needs of preterm children and allow for the provision of targeted early intervention. However, she warns that given the complexity of language development, controversy exists regarding the prognostic value of early testing in children later identified with language impairment, as deficits and certain subdomains of complex language function may not be evident when children are tested at an early stage.

Adi-Japha et al. (2011) studied the time-course of the acquisition of motor (including graphomotor) skills in typically developing preschool children and their peers with language impairment. Their findings indicate that when given a graphomotor learning task, kindergarten children with language impairment (LI) presented an atypical learning curve, differing significantly from the comparison group in the practice phase and in the post-training memory consolidation phase. Given the same training experience, the children with LI showed a late onset of rapid learning. Twenty-four hours post-training only the comparison group showed delayed gains in speed of performance, which were retained two weeks post-training. The children with

LI gained in speed from pre- to post-training, as well as from 24 hours post- to two weeks post-training, but at a cost in accuracy. Although at two weeks post-training they closed the gap in performance speed, they did not perform significantly better than their day one post-training level of performance. The matching procedure used in this study suggests that group differences cannot be explained by graphomotor performance per se, as indicated by the Beery-VMI scores. It should be noted, however, that the Beery-VMI test only measures accuracy of performance, and that the sample was small. This result suggests that children with LI may require more training or perhaps need more off-line time (or both) to show delayed gains. It may be hypothesised that retesting their abilities even later, possibly following some additional training, may demonstrate further improvement. The results of this study corroborate the hypothesis of a typical procedural memory system in children with LI. The results suggest that assessment batteries should incorporate assessment of motor skill learning as well as language in order to identify learning, rather than performance, deficits.

No other research was found to test the possibility of predicting SLI in small children by early developmental (motor) assessment, nor if SLI can be predicted by persisting primary reflexes. Finlay and McPhillips (2013) suggest that the clinical diagnosis of SLI may be influenced by the presence of additional developmental difficulties, which should be made explicit in assessment procedures. Additionally, persisting primary reflexes probably point out that the child has developmental difficulties, but it is not possible to specify which kind of difficulty.

Using a specific movement intervention programme with children with specific language impairment

If motor skills can impact on communicative development, then manipulating movement experiences by easing performance demands so that infants are able to perform movements just outside their capabilities may facilitate advances in communication.

Hitherto, only case studies were performed to investigate the effect of specific movement intervention programmes with children with SLI. In my master's thesis, I showed how inhibiting primary reflexes helps children with suboptimal psychomotor development (which may be caused by persistent primary reflexes and the symptoms arising from these). Here I describe how I worked with a boy (6.5 years old) with a diagnosis of developmental dysphasia (SLI) and dysarthria. By means of special exercises (in Czech "neuro-vývojová terapie") we inhibited all the persisting primary reflexes, which helped him to improve his gross motor skills (catching a ball, riding a scooter, and swimming are no problem for him any more), and fine motor skills such as graphomotor skills and oromotor skills. In speech therapy, he just has to practise the pronunciation of the letter “r”. Balance, crossing the midline with the eyes, and bimanual co-ordination tasks also got better, which shows that his interhemispheric coordination has got better.

Additionally, McPhillips (2000) evaluated the effectiveness of a specific movement intervention programme with children aged 8-11 years old with reading difficulties. He found that it was possible to reduce the level of ATNR interference at this late stage of development and that this led to very significant progress in reading and writing skills.

Summary

Schuele (2004) states that children with an oral language impairment, whether or not they have a concomitant speech impairment, are at great risk of reading disabilities. The reason is quite simple; if the child has difficulties with coding events in spoken language structures and in understanding spoken language, the same difficulties will appear in writing and reading. Therefore, it is important to identify children who may need special interventions. A significant relationship between motor impairment and speech/language impairments in children was found. Further research to seek approaches which can help to mitigate the impairment should be conducted. Typical difficulties lie in the areas of balance, general static coordination, and general dynamic coordination. These can be caused by a cerebellar deficit, as suggested by Estil (2003), but they can also be caused by persisting primary reflexes, as McPhillips showed. Within the context of reading disabilities, children with a history of SLI should be viewed as a subgroup of children with reading disabilities, but no history of speech/language impairment, while the intervention needs of children with SLI are potentially different from those of children with reading difficulties alone. However, we still do not fully understand the causes and biological basis of SLI. As Hill (2001) stated: “The only guaranteed conclusion that one can currently draw is that the deficits of children with SLI are not specific to language.”

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