Asia Pacific Journal of Developmental Differences
Vol. 6, No.1, January 2019, pp. 115—126

Early Markers of Executive Functions and Their Relation to Dyslexia: Cross Patterns and the Level of Initial Activation

Piero Crispiani[1], Mary Mountstephen[2], Eleonora Palmieri[3]

1 *Macerata University – Italy*
2 *University of Reading, United Kingdom*
3 *Psychological and Pedagogical Victor Center, Italy*

Abstract

This article focuses on the importance of executive function and motor control in dyslexia in relation to school readiness in the early years. A functional and a coordinated system of cross pattern communication in the brain is necessary for many everyday actions, for example walking and riding a bike. This is especially true for many higher order functions, relating to school performance, and academic skills such as reading, writing and maths. For this reason, cross patterns are important expressions of effective functioning and the neurophysiological interactions between a range of brain regions for overall inter-hemispheric exchange within the developing brain. Reading is highly dependent on motor planning control, demanding greater efficiency of the cross system, because reading is driven by kinetic organization. This is based on the prompt activation (incipit) of important early markers of executive function which are critical for reading, such as planning direction from left to right, visual tracking, cognitive control, self-regulation, organization in space and time, inhibitory processes and monitoring a state of alertness.
In contrast, when planning is dysfunctional, disorganized, discontinuous and ineffective during a complex cognitive task such as reading, it leads to a disorganized performance that extends well beyond the difficulties in reading and writing identified as dyslexia. In fact, more and more frequently, the phenomenon has been associated with a disorder of executive functions relating to all wider behaviours.

* *Correspondence to:*
Piero Crispiani, Full Professor Macerata University – Italy, Email: pierocrispiani@gmail.com
Mary Mountstephen, Doctoral Candidate at the University of Reading (UK)E: kcsmary1@gmail.com
Eleonora Palmieri, Clinical Psychologist, Director of Psychological & Pedagogical Victor Center, Italy E: palmieri.eleonora1@gmail.com

In our article, the level of this initial activation and execution assumes a central importance in understanding the variability in executive functioning between dyslexic and non-dyslexic students. This reflects executive consistency (fluidity), especially in reading performance, where the dyslexic tends to perform either too slowly or too rapidly. Difficulties in executive function, particularly in neural circuits which depend on effective exchange between the hemispheres, form the basis for our Cognitive Motor Training, utilising cross pattern exercises as part of a larger research programme. The Crispiani Method has undertaken a dynamic approach to training in promoting cognitive enhancement.

Keywords: Cognitive Processing, Self-Regulation, Executive Functions, Dyslexia, Cross Patterns

INTRODUCTION

Since the early years of the 21st Century, a range of concepts have been associated with dyslexia, which are now generating new theoretical stances, within neurological and pedagogic frameworks. As many authors have observed, both in Europe and in the United States (Orton 1929) important contributions have been confirmed in relation to neuromotor, psychomotor, spatial-temporal and coordinative aspects of dyslexia. This progressive support, relating to the emergence of executive disorders, lack of automaticity, proceduralisation, sequencing, and dyspraxia, has led to a paradigm shift (Kuhn, 1962/70) in understanding dyslexia. This relates specifically to the dominant theory of phonological deficit and the range of symptoms involved in the identification of dyslexia, which are now acknowledged to extend beyond phonology.

This new position, driven by neurophysiological and pedagogical developments in neuroscience and education, expands the role of neurobiology, emphasising neuro-psycho-motor views. These are based on a broader analysis of the whole child, which includes disturbances in reading and writing, slowness, disorders in executive processes, involving sequential or procedural order or tracking and space-time elements of human actions, (Chiarenza 1998, 2013, 2014; Crispiani, 2011, 2016; Fawcett Nicolson and Dean, 1996, 2001; Nicolson and Fawcett, 2007, 2010; Stein & Walsh, 2001).

This analysis of the phenomenon of dyslexia leads towards a more organic theoretical framework based on the convergence of cognitive and motor vectors into a cognitive motor paradigm, (Crispiani, 2011; Crispiani & Palmieri, 2017; Leismann et al., 2016).

DEVELOPMENT OF MOTOR SKILLS

There is a growing awareness, both at research level and within the educational community, about the significance of the role that physical aspects of development contribute to cognitive skills and development.

Historically, motor development and cognitive development have been studied as two separate areas, with an understanding that motor development precedes cognitive development. The terms 'movement' and 'motor' are often used interchangeably, although the term 'movement' is used more in relation to observable behaviours in posture or locomotion, whereas the term 'motor' refers more to non-observable neurological processes associated with observable movement. (Carta et al.). The term cognitive-motor reflects more precisely the dynamic inter-relationship between motor development and children's understanding of the physical and social contexts that they inhabit, and the influence of motor skills on perceptual and cognitive processes (Libertus and Hauf, 2017).

These authors suggest that the relationship between motor skills and other developmental domains is particularly strong in the first three years of life, diminishing after this point, apart from a continuing relationship between motor skills and Maths, until the age of six. The implication is that the developmental status of fine motor skills, static balance and other motor skills can be predictive of cognitive skills and, as such, should perhaps play a greater role in establishing school readiness and in providing early intervention programmes that target motor skills.

This is supported by the research of Grissmer et al., (2010) that suggests that evidence from neuroscience and associated research indicates the significance of early motor skills in relation to later cognitive development. They cite neuro-imaging evidence of two-way neural communication between motor and cognitive areas that is also congruent with current embodied cognition research. Koziol, Ely Budding & Chidekell, (2011) also stress the importance of the links between cognitive and motor functions and suggest that motor activity plays a substantial role in the development and performance of cognitive actions.

Effective cognitive-motor development can be perceived as a necessity for adequate physical and healthy psychological development as well as sensory-motor, language, perception, higher cognitive functioning, and emotional and social development. The implication is that these should be taken into account in all school teaching, including a greater emphasis on motor education.

It is interesting to note that there is a developing interest in the interdependence of cognitive and motor development that is reliant on mature vestibular and proprioceptive senses that develop through an active early childhood. It is acknowledged that

practitioners report that children are less ready for school than 10 years ago, however, Frostig, (1970) was making comparable statements nearly 50 years ago. McClelland, Pitt and Stein (2015) have also drawn on evidence from neuroscience and psychology that has highlighted what they refer to as a 'radically different model' of brain/ body systems, that links into the current work on embodied cognition (Ionescc and Vasc, 2014). This implies that our bodies and perceptually guided motions are critical in achieving our goals.

Links between learning and acquiring accurate muscle control and higher level elements of cognition and executive function skills have formed the basis of a physical activity intervention that includes visual tracking and cross lateral activities that have produced encouraging improvements in research studies relating to standardized literacy and numeracy tests (Palmieri and Crispiani, 2015; Crispiani and Palmieri, 2017).

EXECUTIVE FUNCTIONS

Observation of dyslexics indicates that there is a tendency for disorganized performance in complex cognitive tasks, which means they are dysfunctional, ineffective and lacking in fluency. Combining cognitive-motor and educational influences allows us to understand Executive Functions and their variations in order to activate useful interventions from an early age.

Focusing on the qualitative nature of the disorder, rather than the quantitative aspects, a series of deficits in executive functions can be identified. These are, important components of human action, defined as 'ordered and fluent execution of intentional actions in relation to environments'. They* are related to a number of neurophysiological conditions that optimise global human action: general coordination, activation (the 'incipit' or speed of initiation of action) self-regulation, spatial-temporal organisation, lateral dominance and emotional control.

The approach we propose opens up an analytic perspective with a strong neurophysiological basis drawing on theoretical approaches in the management of executive disorders in relation to:

Attention to complex underlying neurophysiological processes rather than perceptual processes

- Cognitive processing speed
- Information processing speed
- Speed of initiation (incipit)
- Self-regulation and self-inhibition processes
- Inter-hemispheric fluidity

* *Cfr. P. Crispiani, Dislessia come disprassia sequenziale, edizioni junior Parma 2011, p.145*

CORRELATION WITH READING-WRITING

Many researchers, since the early 20th century, have theorized about the complex connections between the neurophysiological and neuro-motor processes that are today defined as executive functions, and how these relate to reading, writing, or in other cases, language. Diamond, (2013) for example highlights the importance of executive function in both school readiness and school success notably that inhibitory, control working memory and higher order skills of cognitive flexibility can be improved. She also notes that children who show the greatest deficits can benefit most from programmes that emphasise motor training with repeated practice, where demands are incrementally increased over time. Moreover, Diamond and Kelly (2011) report research showing that aerobic exercise that ramps up in difficulty which includes bi-manual co-ordination is effective in sustained improvement in Executive function.

Supported by motor coordination, spatio-temporal organization, visual tracking, fluidity, and brain plasticity, activities such as reading, writing and mathematics require broad functional activation and intense solidarity between anatomical-functional structures and brain networks. These are implicated in horizontal tracking from left to right, maintenance of fluidity, brain elasticity and many other functions.

Reading and writing are complex processes that are multi-componential by nature, (Karmiloff-Smith et al.) and that require a global neurophysiological and psychological engagement. This can also be linked to motor-praxic efficiency, spatio-temporal organization and fluid movement in the appropriate direction, including cross patterns to change sentence and the speed of semantic and symbolic processes.

CROSS PATTERNS

A functionally dynamic, neurophysiological system that is flexible, with effective hemispheric communication and coordination, supports many daily and automatic actions, as well as many higher functions that have been implicated in literacy and numeracy skills. In this respect, effective inter-hemispheric communication underpins the reading process, that is a kinetic process, linked to the control of motor planning through prompt activation of important early markers of executive function. These include readiness to start or initiate action (the 'incipit'), the planning of left/ right, high/low, perceptual pursuit, cognitive control, self-regulation, organization of space and time, inhibitory processes and vigilance in maintaining alertness.

In contrast, a dysfunctional, discontinuous and ineffective programming of these executive markers, in the context of a complex cognitive task, such as reading, leads to a disorganized performance far beyond the difficulties of the reading process that is recognized as dyslexia. In fact, increasingly, the phenomenon is associated with a disorder of executive functions linked to many aspects of behaviour.

In this article, we wish to raise issues relating to the central importance of intra- and inter-individual variability in executive functioning between dyslexic and non-dyslexic students in terms of executive consistency (fluidity), especially in reading performance, where the dyslexic tends to perform either too slowly or too rapidly. Difficulties in executive functions, with particular reference to neural circuits, whose functionality requires effective exchange between the hemispheres, forms the basis for our Cognitive Motor Training, utilizing cross-pattern exercises as part of a larger research programme. The Crispiani Method has undertaken a dynamic approach to training in promoting cognitive enhancement designed to enhance executive functions.

TREATMENT AND EVALUATION

Cognitive Motor Training, as we define it, has developed as an intensive and ecologically valid practice that builds in sensitive instrumental recording and documentation of practice. The approach monitors fluidity and accuracy in designed to build a general improvement in motor- cognitive engagement and the rapidity of response. This leads more specifically to functional gains in performance in literacy and numeracy skills.

CROSS PATTERNS AND THEIR CORRELATION WITH EXECUTIVE FUNCTIONS IN READING PROCESSES.

The ability to perform a series of exercises is based on the ability to create a mental representation of the sequence required, in response to the therapist's request. So, a cross pattern of the upper limbs (for example, touching the left ear with the right hand and the right ear with the left hand) or the lower limbs (touching the left knee with the right hand) with the left hand the right knee) is dependent on both the necessary motor and ideomotor planning (the syntax of the movement-action based on involuntary movements driven by thought), and the orderly execution and organization in space and time.

This sequence of actions acts as a mental representation and intentional neurophysiological automatisation. In order to understand this, an analogy can be drawn to many actions in everyday life, such as climbing or going downstairs, walking, cycling, or even more complex performances such as reading and writing. The brain areas assigned to the execution of a crossed pattern with upper and lower limbs are in the parietal lobe of the left hemisphere which is specialized to carry out this movement, which involves the right side of our brain (Chiarenza, 2008).

Cross neuromotor patterns involve crossing the midline based on ideas and spatial input, which generate a practical executive output. This output is activated and controlled by the primary prefrontal and premotor cortex. When there is an efficient cross system, reading and writing are praxic-motor processes, as are working with

numbers or deciphering the clock: they are processed in the brain through a cross-modal process.

In dyspraxia, cross patterns are in general slow and poorly coordinated, even in terms of slowness of thought, orientation and perception leading to slowness in terms of cross pattern processes. Inaccuracy in the opposite side of the body, leads to an altered kinesthetic sense involving disorder and lack of fluency.

Reading and writing are, seen as highly automatic ideomotor praxes, or practical ideas or thoughts which cannot be seen. They are based on cross pattern processes, which activate complex simultaneous functions (Crispiani & Palmieri 2015).

The conceptual input and its prompt reception is also important, since a slow neuro-activation (incipit) makes transfer to the frontal lobes disorganized

It has been observed that children in kindergarten sometimes have an early ideomotor representation of words, in line with their verbal skills. This means that even if they cannot read yet, they can intuitively write or read words as a global gestalt. This corresponds to the logographic stage identified by Frith, (1985) in early reading, where the word is recognized as a whole rather than in terms of the component letters. This means that young children may recognize familiar logos, despite the fact they cannot yet read.

This suggests that from the early years, children read through a gestalt approach (a global, intuitive approach) and they continue as in automatic reading, as an internal motor process, with a representation of the text, scrolling from left to right, applying a pattern crossing the midline.

Fluid reading is consistent reading, without interruptions or stumbling, a kinesthetic process which involves, as an ideomotor praxis, both the lower parietal occipital association areas and the visuo-kinesthetic representations in the left hemisphere.*

In the dyspraxic / dyslexic profile, (Crispiani, 2013) this ideomotor function demands a greater organizational and self-regulating input, due to their disordered and dysfluent processing. This makes the child awkward and clumsy in execution, with activation which is slower and not always accurate compared with the control group (Crispiani & Palmieri 2017)

In our observations, the control group spontaneously crossed the midline, with both arms and both legs. They were able to perform this task without interruptions or hesitations maintaining both speed and accuracy. In comparison, the dyslexic group is slow and their performance is less accurate

* *Chiarenza, e Njiokiktjien. (2008). Le disprassie dello sviluppo e i disturbi motoriassociati, Suyi, Amsterdam.*

Therefore, an efficient cross system based on prompt and adequate neuro-activation which we call the *incipit or initiation of action (*Crispiani 2016*)*, without interruptions or pauses, may ensure fluid and consistent reading.

In the research example examined there was an absence of visual deficits. This means the cognitive representation of the crossed patterns depends on correlated executive functions. These become the first indicators of the reading processes: the *incipit,* ideomotor planning, inhibition, and self-regulation.

EXECUTIVE FUNCTIONS AND FUNCTIONAL GAINS

What is the basis of an efficient executive system, that allows both projection and execution of actions (Chiarenza & Njiokiktjien 2008)? A kinesthetic mental representation has an important function in providing activation on request in the pre-frontal areas of the brain. This aspect is central to the execution of ideomotor praxis, putting thought into motion.

The dyslexic group examined in the research sample (Crispiani & Palmieri, 2017) manifested different levels of disorders in ideomotor representations including:

- Poor fluidity and synchronization of the spatial and temporal elements implicated in the cross (inter-hemispheric) systems.
- A tendency to clumsiness and inaccuracies in the dynamic coordination of skills required to complete tasks efficiently.
- Inability to reproduce the initial phase of targeted patterns, substituting actions or using other body parts.

In this case, the body requires crucial spatial parameters during the fluid execution of cross pattern sequences.

This requires:

- Adequate crossing of the medial axis or mid line
- Coordination and laterality
- Rhythm and control of the body
- Timing clearly emerged from our research as a significant concept for the dyslexic group. They showed delays from initiating to executing actions, based on slow neuro-activation including:
- Lack of coordination in motor sequences
- Irregular timing and rhythm, with difficulties in sequential proceduralization of the target pattern
- Alterations in the spatial input required for efficient actions

This means that the dyslexic group never developed automatic processing of the sequence they were asked to perform, so that the exercise routine remained effortful, stressful, uncoordinated and slow.

Performing a fluid cross pattern sequence is part of an internal representation that requires electric potentials in preparation for motor planning (Vidal, Bonnet, Macar, 1995) before action. The slowness that the dyslexic demonstrates in the *incipit* or initiating phase implicates the role of tempo, in particular in relation to reading. This is an internal process where the dyslexic manifests slowness in cross pattern executions.

From this perspective, some authors point out the importance of training executive functions to promote learning through motor training programmes. These should employ a series of dynamic progressiveness and incremental procedural patterns (Bergman-Nutley, Söderqvist, Bryde, Thorell, Humphreys, & Klingberg, (2011). Children with difficulties in motor coordination and reduced self-regulation skills may achieve great benefits from this training (Diamond & Lee 2011) with those with the greatest difficulties showing the greatest improvement.

Linked to this, the Special Training, Champion LIRM (Crispiani & Palmieri 2017), as applied in our research, is a professional and clinical practice based on the *Maturation Process* to achieve automaticity. The Special Training applied uses an incremental pattern of exercises through increasing the number of sequences and the speed of execution.

What this produces is a neurophysiological acceleration that trains slow and disorganized functions, normally highly dysfunctional in dyslexics, This is a disharmonic condition, in the initial or preparation phase that we define as the *'incipit'*.

In the dyslexic group the execution of cross patterns was slower than the control group in the initiation and planning phases, where the control group required less time. This slow initial activation provides evidence of the difficulty of the dyslexic in readiness to start, with an underlying slowness in neuronal circuits.

This lack of promptness in the dyslexic is related to self-regulation processes and linked to kinesthetic feedback. In many cases, motor perseverance is revealed in the dyslexic group, in terms of repetitions of the same wrong patterns (for example the dyslexic group may not cross arms at the shoulders whilst walking on the spot, or they continue to walk on the spot, without crossing for some seconds.

It is acknowledged that a lack of skill in inhibiting ongoing behaviour is related to the orbitofrontal cortex based on a disorder of executive functions.

Following the Special Training Champion LIRM (15 hours in 3 days), the improvement of

speed activation of the dyslexic group was 56% (Crispiani & Palmieri 2017 and b). Our empirical research was applied to a small sample and limited to a dyslexic context, nevertheless it showed a normalization of speed in our dyslexic group, moving towards the level identified in the control group. Its purpose is to show that there is a possible link between cross (interhemispheric) systems, executive functions and the reading process.

CONCLUSION

It is proposed that EFs can be improved. Moreover, the level of their initial activation is centrally important in determining dyslexic's efficiency. This is especially true in tasks occurring within the same time frame, where the dyslexic - dyspraxic tends to be even more slow. This is due to a difficulty in central neurophysiological processes, particularly interhemispheric exchange and executive functions. Cognitive–Motor-Training enhances the consistent and persistent coordination of cross systems in the lower and upper limbs, in general praxic performance, stressing their readiness or rapid activation. The promptness, the efficiency, the consistency and self-regulation of the activation of these aspects, constitute the active principles underlying the practices of our Practical-Theoretical Cognitive Motor Training (Crispiani, 2016a). Despite the very significant improvements the dyslexic participants have made in all their skills, further research is needed using this approach in order to further validate these promising findings that can reinforce traditional intervention.

REFERENCES

Bergman-Nutley, S., Söderqvist, S., Bryde, S., Thorell, L. B., Humphreys, K., & Klingberg, T. (2011). Gains in fluid intelligence after training non-verbal reasoning in 4-year-old children: A controlled, randomized study. *Developmental Science 14*(3):591-601

Chiarenza, G. A., Di Pietro, S., & Casarotto, S. (2014). The psychophysiology of reading. *International journal of psychophysiology*, *94*, 111-119.

Chiarenza, e Njiokiktjien. (2008). *Le disprassie dello sviluppo e i disturbi motoriassociati,* Suyi, Amsterdam.

Chiarenza, G. A., & Stagi P. (1998). Is timing control a central deficit underlying developmental dyslexia? *International Journal of Psychophysiology, 30*, 1-2,72-73.

Chiarenza, G. A., Olgiati, P., Trevisan, C., De Marchi, I., & Casarotto, S. (2013). Reading aloud: A psychophysiological investigation in children. *Neuropsychologia*, *51*, 425–436.

Chiarenza, G. A., Di Pietro, S. F., & Casarotto, S. (2014). The psychophysiology of reading. *Proceedings of the 17th world congress of Psychophysiology (IOP2014),* of the International Organization of Psychophysiology (IOP) Hiroshima, Japan September 23- 27, 2012, Guest Editors: Hiroshi Nittono, Keiichi Onoda, Hideki Ohira

Crispiani, P. (2011). *Dislessia come disprassia sequenziale* , Junior-Spaggiari, Bergamo-Parma.

Crispiani, P., & Palmieri, E. (2012). *Champion LIRM*, Institute Itard, Centro Italiano Dislessia and Disprassia

Crispiani, P. (2015). *Hermes 2016. Glossario scientifico professionale*, Junior- Spaggiari, Parma.
Crispiani, P. (2016a). *Il Metodo Crispiani 2016. Clinica della dislessia e disprassia,* Ed. Junior-Spaggiari, Parma.
Crispiani, P., & Pavone, M. (2016b). Pedagogia speciale e condizione dislessica, in P. Crispiani (a cura), *Storia della pedagogia speciale*, ETS, Pisa, pp. 722-744.
Crispiani, P., & Palmieri, E. (2017a). *Champion Pressing, pratiche intensive speciali di Cognitive Motor Training,* by stituto Itard, Collana Les Sauvages, Chiaravalle (AN)
Crispiani, P., & Palmieri, E. (2017b). Dyslexia and Champion L.I.R.M: Outcomes of a research study based on treatment of cross Patterns. *Asia Pacific Journal of Developmental Differences 4*, 2, 195—211 DOI: 10.3850/S2345734117000113
Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, 333(6045):959-64. doi: 10.1126/science.1204529.
Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64*, 135–168. http://doi.org/10.1146/annurev-psych-113011-143750
Fawcett, A. J., Nicolson, R. I., & Dean, P. (1996). Impaired performance of children with dyslexia on a range of cerebellar tasks. *Annals of Dyslexia, 46*, 259-283.
Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. Patterson, J. Marshall, & M. Coltheart (Eds.), *Surface dyslexia: Neurological and cognitive studies of phonological reading* (pp. 301- 330). Hillsdale, NJ: Lawrence Erlbaum. https://sites.google.com/site/utafrith/publications-1/reading– spelling-and-dyslexia
Frostig, M. (1970). *Movement education: Theory and practice.* Chicago: Follet Educational Corporation
Galaburda, A., & Livingstone, M. (1993). Evidence for a Magnocellular Defect in Developmental Dyslexia. *Annals of the New York Academy of Sciences*, 682, 70-82.
Grissmer, D., Grimm, K., Aiyer, S., Murrah, W., & Steele, J. (2010). Fine motor skills and early comprehension of the world: Two new school readiness indicators. *Developmental* Psychology*, 46, 1008-1017.*
Hauf, P., & Libertus, K. (2017). Editorial: Motor skills and their foundational role for their foundational role in perceptual, social and cognitive development. *Frontiers in Psychology*, *8,* 301.
Koziol, L., Ely Budding, D., & Chidekel, D. (2011). From movement to thought: Executive function, embodied cognition and the cerebellum. *Cerebellum*: DOI 10.1007/s12311-011-0321-y
Kuhn, T. (1962/70). *The Structure of Scientific Revolutions*, Chicago: University of Chicago Press (1970, 2nd edition, with postscript
Leisman G., Moustafa A. A., & Shafir, T. (2016). Thinking, Walking, Talking : Integratory Motor and Cognitive Brain Function, in *Frontiers in public health*, 25 may. https:// doi.org/10.3389/fpubh.2016.00094
McClelland, E., Pitt, A., and Stein, J. (2015). Enhanced academic performance using a novel classroom physical activity intervention to increase awareness, attention and self-control: Putting embodied cognition into action. *Improving Schools 2015*, *Vol 18*(1) 83-100)
Nicolson, R. I., & Fawcett, A. J. (2007). Procedural learning difficulties: reuniting the developmental disorders? *Trends in Neurosciences*, *30* (4), 135- 141.
Nicolson R. I., Fawcett, A. J., & Dean, P. (2001). Developmental Dyslexia: the cerebellar deficit hypothesis, *Trends in Neurosciences*, *24* (9), pp. 508-511.
Nicolson, R. I., & Fawcett, A .J. (2010). *Dyslexia, Learning and the Brain*. MIT: Massachusetts.
Orton, S. T. (1929). Word-Blindness in school children, *Arch. Neur Psychiatric*, *21*.
Orton, S. T. (1937). *Reading Writing and speech problems in children*, Freeman, San Francisco.

Palmieri, E., & Crispiani, P. (2015). Improving the fluidity of whole word reading with a dynamic coordinated movement approach *Asia Pacific Journal of Developmental Differences 2*, pp 158 - 183 DOI: 10.3850/S2345734115000277

Stein, J., & Walsh, V. (1997). To see but not to read; the magnocellular theory of dyslexia *Trends in Neuroscience*, *20* (1997), pp. 147–152 591 -601

Vidal, F., Bonnet, M., Macar, F. (1995). Programming the duration of a motor sequence: Role of the primary and supplementary motor area in man, *Exp Brain Res* 106:339-50