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# Low-cost movement analysis in children with specific learning disorders: A two-case report

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**Abstract**

In child rehabilitation, there is a need for assessment tools able to detect even small deficits and subtle changes in order to plan and verify the rehabilitative programme. However, as current methods are mainly based on optoelectronic expensive and non-portable devices, they tend to lack practicality and/or reliability and good validation. We present two cases of children with a specific learning disorder involving writing skills; both received treatment to improve their motor and visuomotor skills involved in the act of writing. In addition to neuropsychological testing, the assessment included a new non-invasive method, based on quantitative videoanalysis of arm movement during a maze task; moreover, parent and teacher were interviewed. The low-cost method seems promising, but it seems to measure something different from the perception of teachers and parents and from commonly used neuropsychological tests.

Keywords: Rehabilitation, child, visuomotor skills, neuropsychological tests.

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## 1. Introduction

Arm movements are the final result of a highly complex mechanism involving motor algorithms that are shaped according to motor experience (Wolpert & Gahrahmani, 2000). The brain network involved is complex and not yet completely understood (D'Angelo, 2010). Stability and adaptability of motor performances are lifelong fundamental to develop 'skillful' actions (Schneiberg, Sveistrup, McFadyen, McKinley & Levin, 2002). Adults have highly stereotyped reaching movements and therefore the arm's trajectories are rather stable, so that joint angles at any given moment are well defined. Studies with complex optoelectronic systems in healthy subjects have shown that upper limb's motor trajectories are highly variable before the age of 3 and then tend to became more and more stable; when the child is about 11, he resembles adults from this point of view (Sveistrup, Schneiberg, McKinley, McFadyen & Levin, 2008). Moreover, planning an upper limb's gesture implies for the child the ability to stabilise the head during postural and kinetic activities (Assaiante, Mallau, Viel, Jover & Schmitz, 2005).

Reaching movement's alterations are reported in children with ADHD, but they are generally considered secondary to a coexisting congenital deficit (usually referred to as deficits in attention, motor control and perception) (Gillberg, 2003). This implies that motor coordination disorders are to be searched also in those patients presenting for ADHD, especially when they are dysgraphic (Di Brina, Nielsb, Overvelde, Levi & Hulstijn, 2008). The study of writing skills generally relies on neuropsychological pen-and-paper tests, but the need for well standardised and reliable tools has been underlined (Chiappedi, De Bernardi, Dalla Toffola & Bejor, 2010).

Writing can be studied, from a kinetic point of view, as the result of specific periodic movements inscribed on coordinative patterns, whose control has characteristics similar to a couple of non-linear oscillators (Athenes et al., 2004). This system needs a sufficient integration of visual perception, so that any disorder reducing visual acuity and/or eye coordination can impair it (Racine et al., 2008). The neural systems involved are complex and widespread, and have not been completely understood (Paz & Vaadia, 2009).

However, Weil and Amundson (1994) define visual – motor integration as the ability to coordinate visual information with a motor response: efficient eye-hand coordination is particularly important in pre-school and in the school years in order to perform writing precursor gestures useful to learn how to write (Van Hoorn et al., 2010).

In child rehabilitation, there is a need for assessment tools able to detect even small deficits and subtle changes in order to plan and verify the rehabilitative programme (Chiappedi et al., 2010). However, as current methods are mainly based on optoelectronic expensive and non-portable devices, and tend to lack practicality and/or reliability and good validation (Gravenhorst & Walter, 2009), we decided to test a different assessment system.

## 2. Methods

A very preliminary test to assess the possible utility of our tool in a rehabilitative setting was conducted on two children, seen for diagnostic issues at the 'C. Mondino' National Neurological Institute and for their rehabilitation at the 'Santa Maria alle Fonti' Medical Center of the Don Carlo Gnocchi Foundation. They were randomly chosen among those with a diagnosis of a learning disorder (both specific or non-specific), with a significant impairment of writing (in terms of visuomotor skills, including the so-called 'Evolutive Dysgraphia') and without any history of injuries involving the arms in the past 3 years or of any progressive or stabilised major motor or orthopaedic disorder.

We studied the same gesture used in our preliminary study (Chiappedi et al., 2010) and in a later study meant to offer normative data (Chiappedi, Togni, et al., 2012). It consisted in driving a cursor out of a labyrinth projected in front of the child by moving a wireless mouse on a table plane. We used rightwards orientation to mimic writing. The labyrinth was drawn in white, on a black background, and was quite wide; it was generated with PRINC – Reaction Times, a software that we had developed. In order to maintain the subject's back and head straight and the visual perpendicular to the projected labyrinth, we used a tripod to adjust in height the sitting position. After these regulations, the subject's forearm was lying on the table with the elbow flexed at about 120°.

The child was asked to drive the cursor out of the labyrinth as fast as he could without touching the walls (FASTER condition) or to try not to 'hit' the walls while running the maze (ERROR condition). These different instructions were given in random order, since we knew from our previous studies (Chiappedi-Togni, et al., 2012) that there was no order effect; we left an interval between one session and the other to prevent immediate repetition learning effect. The performance was captured with a camcorder CASIO Exilim EX F1, placed behind the child, 2 m high and skewed downwards 120° (so as to equal the humerus inclination on the forearm). We assessed shoulder, elbow and wrist angles on the horizontal plane during motor tasks with a sampling rate of 125 Hz, using virtual markers generated by DartFish Pro Suite 5.0 software and placed on specific bone landmarks. Performances of our two patients were compared to the normative data provided by our previous study (Chiappedi-Togni, et al., 2012).

The treatment offered was a psychomotor therapy lasting 16 sessions. The programme of this treatment included two main parts: a non-specific training of motor coordination and visuomotor integration (also including some motor relaxation exercises) and a specific training of pen grasping, visuomotor integration in the act of writing and so forth. All the exercises were performed under the supervision of an expert psychomotor therapist, who acted first as a guide and later as a coach, suggesting possible improvements to the strategies already used by the child. A significant part of each session was devoted to discussing what the subject had felt and experienced while performing the exercise, to increase his body awareness and to improve his management of emotions connected with motor experiences (Grandi, Mazzola, Angelini & Chiappedi, 2012; Olivieri et al., 2013).

## 3. Results

The first patient was a 7-year-old boy who had a diagnosis of 'delay of graphomotor development and frailty of reading and writing skills in a child with a mixed emotional and conduct disorder'. The diagnosis was reached after accurate testing of different components (emotional status, general intelligence, specific neuropsychological functions such as attention, motor skills, reading skills, writing skills in terms both of motor and orthographic competencies and so on). He was seen and started psychomotor treatment when attending the second year of primary school.

A comparison of his performances before and after the psychomotor training (meant to increase his visuomotor skills) with those expected according to our normative data (Chiappedi, Togni, et al., 2012) is shown in Figure 1. Looking at the figure, you can see how the child at the end of treatment focused his range of motion on the elbow, moving much closer to the values expected for his age. The teachers observed a marked improvement in both the grasping of the pen or pencil and the writing skills (in terms of readability); this led also to an improvement in the marks in areas where these were relevant skills.

The second patient was a 9-year-old boy with a diagnosis of 'Evolutive Dyslexia; Evolutiva Dysorthographia; deficit of planning, visuomotor and attentive skills'. The diagnosis was reached after accurate testing of different components (emotional status, general intelligence, specific neuropsychological functions such as attention, motor skills, reading skills, writing skills in terms both of motor and orthographic competencies and so on). He was seen and started psychomotor treatment when attending the fourth year of primary school.

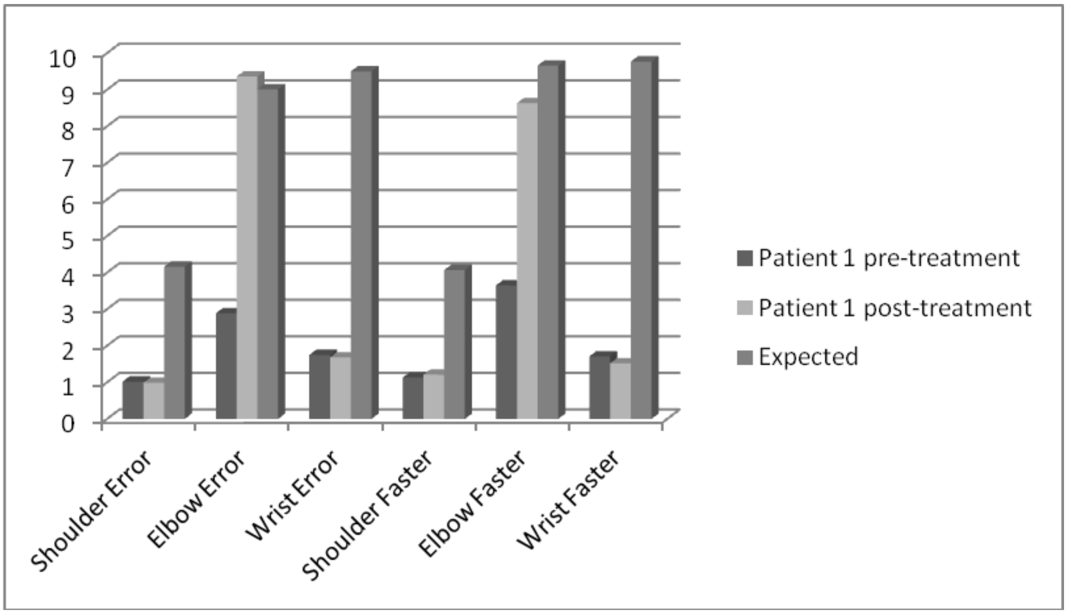


Figure 1. Patient 1 ranges of motion

A comparison of his performances before and after the psychomotor training (meant to increase his visuomotor skills) with those expected according to our normative data (Chiappedi, Togni, et al., 2012) is shown in Figure 2. After the rehabilitative treatment, this patient increased his focusing of the joint movements on the shoulder, therefore, getting far away from what was expected (i.e., a progressive focusing on the wrist, with a secondary but significant role played by the elbow). Still his performance, as evaluated by his teachers, improved in a significant way.

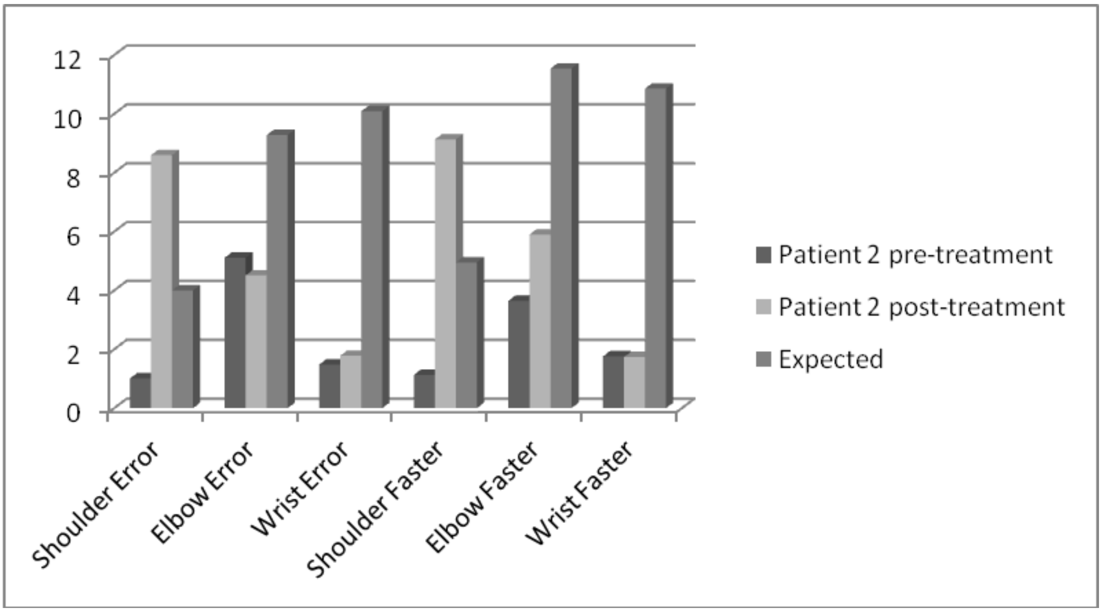


Figure 2. Patient 2 ranges of motion

## 4. Discussion

It is possible that there were different pathways leading to functional improvement in these two patients. The first probably developed better visuomotor control of writing; the second had a planning and attentive deficit and it is possible that the improvement of his academic results was due to an improvement in these neuropsychological abilities (which are not measured by our test). We also cannot exclude a contribution of emotional factors, including an improved management of anxiety and/or other emotions (Chiappedi & Baschenis, 2016) or to other factors not evaluated in our study. Our tool was well accepted by the two children, as expected from previous studies in children and in adults using a similar methodology (Bejor, Mandrini, Caspani, Comelli & Chiappedi, 2015; Chiappedi et al., 2013). This acceptability of the techniques used is of high importance to increase childrens' compliance and to prevent treatment refusal (Chiappedi et al., 2009; Chiappedi, Panizzari & Bejor, 2011).

## 5. Conclusion

These preliminary findings are stimulating and promising, although as for commonly used neuropsychological testing, caution in the interpretation of results is required (Chiappedi, Baschenis, Dolci & Bejor, 2011; Chiappedi et al., 2012).

## 6. Recommendations

Future studies are already planned to complete the development of this tool and to test its possible utility. These studies will include a larger population with both male and female children.

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