Research in Developmental Disabilities 32 (2011) 1004–1010

Contents lists available at ScienceDirect

Research in Developmental Disabilities

A new approach for the quantitative evaluation of drawings in children with learning disabilities

Manuela Galli [a,b], Sara Laura Vimercati [a,*], Giacomo Stella [b,c], Giorgia Caiazzo [b], Federica Norveti [b], Francesca Onnis [b], Chiara Rigoldi [a], Giorgio Albertini [b]

[a] Dept. of Bioengineering, Politecnico di Milano, p.zza Leonardo Da Vinci 32, 20133 Milano, Italy
[b] IRCCS "San Raffaele Pisana", San Raffaele SPA, Roma, Italy
[c] Dept. of Education and Human Sciences, University of Modena and Reggio Emilia, Italy

ARTICLE INFO

Article history:
Received 17 January 2011
Received in revised form 25 January 2011
Accepted 25 January 2011
Available online 23 February 2011

Keywords:
Denver Developmental Screening Test
Learning disabilities
Drawing test
Optoelectronic system

ABSTRACT

A new method for a quantitative and objective description of drawing and for the quantification of drawing ability in children with learning disabilities (LD) is hereby presented. Twenty-four normally developing children (N) (age 10.6 ± 0.5) and 18 children with learning disabilities (LD) (age 10.3 ± 2.4) took part to the study. The drawing tasks were chosen among those already used in clinical daily experience (Denver Developmental Screening Test). Some parameters were defined in order to quantitatively describe the features of the children's drawings, introducing new objective measurements beside the subjective standard clinical evaluation.

The experimental set-up revealed to be valid for clinical application with LD children. The parameters highlighted the presence of differences in the drawing features of N and LD children. This paper suggests the applicability of this protocol to other fields of motor and cognitive valuation, as well as the possibility to study the upper limbs position and muscle activation during drawing.

1. Background

Simple drawing tests are commonly used for the clinical evaluation of cognitive capabilities in children. Around 1930 Goodenough empirically demonstrated that children's drawings reflect their intellectual skills and development too; based on this belief he developed the Draw-A-Man test and a dedicated cognitive scoring system to measure the children's ability to form abstract concepts (Abell, von Briesen, & Watz, 1996). Since then several graphic tests have been developed for the cognitive evaluation of children, such as the Denver Developmental Screening Test (DDST) (Frankenburg, Dodds, Archer, Shapiro, & Bresnick, 1992), that evaluates both gross and fine motor functions; in particular, among other requests, the child is asked to copy the figures of a circle, a square, and a cross. Although copying a figure does not require memory retrieval, it requires a translation process between the perceptually extracted relationships and the degree of available drawing skills that elicit a wide range of joint-coordination patterns. Also, a copying task requires the child to consider the visual form (figure) as well as the neuromuscular adjustments for line control, direction, speed and pressure (Khalid et al., 2010).

* Corresponding author. Tel.: +39 02 2399 3359; fax: +39 02 2399 3360.
E-mail addresses: manuela.galli@polimi.it (M. Galli), sara.vimercati@polimi.it, vimercati.sara@gmail.com (S.L. Vimercati), giacomo.stella@unimore.it (G. Stella), giorgiacaiazzo@yahoo.it (G. Caiazzo), f.norveti@gmail.com (F. Norveti), francescaonnis@gmail.com (F. Onnis), chiara.rigoldi@polimi.it (C. Rigoldi), giorgio.albertini@sanraffaele.it (G. Albertini).

0891-4222/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ridd.2011.01.051

The graphic tests are administered to evaluate the performance of children at risk for school problems (Bayoglu, Bakar, Kutlu, Karabulut, & Anlar, 2007; Perera, 2005), children with developmental coordination disorders (DCD) and/or learning disabilities (Smits-Engelsman, Wilson, Westenberg, & Duysens, 2003; Rosenblum & Livneh-Zirinski, 2008), children with autism (Sheppard, Ropar, & Mitchell, 2007; Sheppard, Ropar, & Mitchell, 2009), children with cerebral palsy (CP) (Bumin & Kavak, 2010), children with neurofibromatosis type 1 (NF1) (Gilboa, Josman, Fattal-Valevski, Toledano-Alhadef, & Rosenblum, 2010) and in the assessment of learning disorders (Mati-Zissi, Zafiropoulou, & Bonoti, 1998; Rosenblum, Dvorkin, & Weiss, 2006).

The assessment of these tests nowadays, in clinical routine, still remains mostly qualitative and based on the visual evaluation made by the operator. The drawings are administered using the "pen and sheet method" and are given a score with respect to the presence or absence of some features (for instance number of particulars in the "Draw-a-Man" test (Abell et al., 1996)) or to the "correctness" of the drawing in the DDST (for instance if the child draws a closed-figure circle (Frankenburg et al., 1992)). This method of evaluation has of course important limitations due to the qualitative (instead of quantitative) evaluation of the drawings, as well as to the lack of information about the kinematics aspects of movement (velocities, starting and ending point, pen lifts...). Besides this no evaluation of the upper body joints movements and the related posture of the trunk and the head during the execution of the writing are provided.

Among the disorders that are majorly assessed by means of graphic tests there are the learning disorders (LD), which occur in about 5% of school-aged children (Lagae, 1998), and consist of different learning problems, the most common of which are dyslexia and dysgraphia. As the LD children have specific drawing and writing difficulty due to a variety of perceptual-motor and learning problems (Mati-Zissi et al., 1998; Rosenblum et al., 2006), graphic tests are fundamental for the assessment of these subjects. The difficulty in the graphic performance may be due to skills such as comprehension of differences, coordination of parts in an organized whole, spatial movement, size-scaling, classification or distinction of figures. Also, it is expected that difficulties in movement and spatial orientation appear in dyslexic and dysgraphic children (Mati-Zissi et al., 1998). As mentioned before, the description of these features in the LD children's drawings is mainly based on visual evaluations, that come from the clinician's experience and from scoring systems, such as the DDST (Frankenburg et al., 1992). Most of the previously mentioned studies are therefore qualitative and subjective, and rely on the observer's experience, with the exception of the studies by Rosenblum et al. (Rosenblum et al., 2006; Rosenblum & Livneh-Zirinski, 2008; Gilboa et al., 2010), in which a computerized graphic tablet was used to extract some quantitative parameters in the writing trace of LD children (such as number of letters per minute, distance between letters, velocity) and the study by Khalid et al. (2010), in which the computerized digitizing tablet was used to study the graphic strategies of the LD children (i.e. starting point of the drawing, sequence of drawing, and pressure).

We can conclude that the study of children's writing disorders and learning disabilities nowadays remains mainly based on a subjective or at least semi-quantitative evaluations. Also, the lack of quantitative parameters contributes to the difficulties in precisely defining the causes of these problems. The aims of this study were thus to develop an experimental set-up for the quantitative evaluation of drawing tests, that could be suitable for children and could help evaluating the standard clinical tests in an objective way. We defined and computed some significant parameters in order to characterize the drawings and applied the experimental set-up to a control group of children and to a group of children with LD, in order to demonstrate the applicability of the set up for clinical utility.

2. Materials and methods

2.1. Participants

Twenty-four normally developing children (N) (age 10.6 ± 0.5) and 18 children with learning disabilities (LD) (age 10.3 ± 2.4) took part to the study. The LD participants were recruited in the IRCCS San Raffaele Pisana Movement analysis Lab in Rome and were diagnosed on the standard criteria for Italian norms (Sartori et al., 1995). All the participants had normal intelligence IQ, and scored 2 z points under the mean in reading. The study was approved by the Ethics Research Committee of the San Raffaele Pisana. All participants were volunteers and their parents gave informed consent to participation in the study.

2.2. Methods

The graphic gesture was acquired with an optoelectronic system with six cameras (SMART-D BTS; Italy), at a frequency of 120 Hz, and with an integrated video system (Vixta, BTS, Italy) for videorecording. The optoelectronic system is an equipment that measures the 3D coordinates (X, Y, and Z) of reflective markers through time. The markers were of diameter = 10 mm and were used in the configurations described here following.

The first configuration, shown in Fig. 1a, was used for a static acquisition, in which the participant did not take part: the pen was laid on the table and the markers were acquired for 5 s, in order to calculate the position of the tip of the pen and allow the calculation of its position during the dynamic acquisition, in which the graphic test was executed by the subject. In the dynamic acquisition markers were positioned both on the sheet and on the pen (as shown in Fig. 1b) (De Pandis et al., 2010).

The pen tip coordinates were therefore reconstructed during the dynamic acquisition: in this way it was possible to obtain the drawing trace (i.e. the drawn figure) and the trace of the pen lifts.