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Assessment of Visuomotor and Visual Perception Skills in Children: A New Proposal Based on a Systematic Review

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Abstract: Vision is a dominant sense in humans and its performance is a critical factor in children's development and learning. For health sciences it is essential to identify the tools most used in the last decade to assess visuomotor and visual perception skills in children under 6 years of age. For that reason, systematic research was conducted according to the PRISMA criteria. The research was performed using B-on and Pubmed and were included articles published between 2011 until 2021. Included were 17 articles highlighting 2 different samples: children with typical development and children with abnormal development. The assessment protocol differs between researches. A large diversity of tests were observed, usually involving "paper and pencil" tasks. Surprisingly, the association of neuroimaging or electrophysiological techniques with traditional assessment is not common in clinical settings. This aspect will be fully analyzed and a proposal of change will be presented.

Keywords: visuomotor skills, visual perception skills, assessment, children

1 Introduction

Vision is the most powerful sense and gives information about our surroundings from the first day of life [1-2], with the visual skills development occurring during childhood [2-3]. At 5 to 6 years of age, the relationship between visuomotor performance, handwriting execution and future verbal number skills is evident [4-5].

Visuomotor integration is the degree to which visual perception and hand finger movements are well coordinated [6]. For many, visual perception can be defined as the interpretation of visual stimuli, the intermediate step between simple visual sensation and the process of cognition [6-9]. In the same way, visual perception could be explained as the ability to extract information from what is seen [10]. The functional use of these skills is fundamental to everyday life and its impact on overall development, social communication and learning has already been reported [11-14]. These skills have been greatly influenced by cerebral components, so they could be an impairment even in children with typical or near-typical visual acuity.

Assessment is a milestone in any (re)habilitation approach and also crucial for the investigation process. In the REHAB – Cycle this is described as a continuous process that involves the identification of individual problems, needs and relates the problems of relevant factors to the person and the environment [15-16]. Assessment of multiple performance areas is essential in understanding children's strengths and limitations and therefore critical for developing a focused intervention plan to improve performance [17]. In pediatric rehabilitation the evaluation tends to use qualitative and quantitative measures. Both in research and in rehabilitation, a holistic approach is currently recommended to better understand and characterize the phenomena under study.

In the last few decades, a considerable revolution in technology has taken place. This provided the opportunity to introduce new tools in health care. In rehabilitation practice these tools could provide benefit from the youngest to the oldest patients [18-21].

Nowadays is consensual that introduction of technology in health is a strong way to improve the quality of care. The maturation of computing technologies has dramatically altered the face of healthcare. Recent technological developments that can be harnessed to replicate, enhance, or create methods for assessment of functional performance [22]. The implementation of this measures will increase the quantity and diversity of digital data and facilitate artificial intelligence. These newest field of engineering when implementing in health care has the ability to cover areas including prevention, treatment and rehabilitation, following the care continuum [23].

1.1 Motivation

In therapeutic practice, the assessment of visuomotor and visual perception skills has been, up until now, uneven. It seems from clinical and therapeutic practice that the lack of a standard protocol or technological equipment limit health professionals from making a structured assessment. Given this knowledge, the main motivation for performing this systematic review is to better know the most common instruments used in the last 10 years to assess visual visuomotor and visual perception skills. This knowledge will guide your reflection to structure a new proposal of assessment that included technology in the assessment phase.

The first aim of the article is to identify the instruments most used in the last decade to assess the visuomotor and visual perception skills in children up to 6 years of age. The second is to present a new assessment proposal that includes a technological solution and could contribute, in the future, for artificial intelligence application.

2 Contribution to Life Improvement

Health professional's performance is dependent upon knowledge and quality tools that are available for a patient's treatment. In our knowledge this is the first systematic review on the assessment of visuomotor and visual perception skills in

children. So, it could be useful to offer a better selection of the tools used in the assessment process of children with visuomotor or visual perception skills impairment. A better assessment is, without a doubt, the basis for better intervention which can contribute to the children's quality of life [17].

Building on the information collected in this systematic review, it is also possible to stimulate the identification of technological solutions that can, in the future, be integrated in the visuomotor and visual perceptive skills assessment. The evidence shows that these two measures are directly related with the increase of professional efficiency and the improvement of the patient's quality of life.

3 Materials and Methods

For this review, the preferred reporting items for systematic reviews and meta-analysis (PRISMA) [24] were followed. As a research strategy two databases were used: Pubmed and ISI Web of Knowledge. In both, the advanced search mode was used. The research was conducted in January 2021, using the following keywords and boolean operators: “visual development” OR “visuomotor” OR “visual perception” AND “assessment”.

Some filters were used: articles from last 10 years, humans, full articles available, children until 18 years old. To select the articles the following inclusion criteria were used:

- 1- Studies that evaluated visual perception and visuomotor skills in the methodology protocol.
 - 2- Research in babies and children of six or less years of age;
 - 3- Original, experimental or observational research published between 2011 and 2021;
 - 4- Published scientific periodical journals with peer reviews;
- and the following exclusion criteria as well:
- 1- Conducted with animal research;
 - 2- The full article is unavailable in the databases used;
 - 3- The paper is in a language other than English or Portuguese.

The temporal window of the last 10 years (2011 until January 2021) was used because the purpose was to collect the most recent methods and techniques used in visuomotor and visual perception assessment in children.

3.2 Selection Method

All the papers that did not follow the inclusion criteria were eliminated. This occurred in the different phases of PRISMA methodology, such as those reported in Fig. 1. At the end of the PRISMA methodology application 17 articles remained to include in the systematic review. It is important to note that some articles included in this review reported investigations that included some children up to six years of age, however, the participants mean age is less than 6 years of age.

3.3 Methodology for Collecting Information

In a systematic review an in-depth, systematic and critical examination is made regarding the object of study. The information is collected and organized to clarify the following aspects: type of study, sample characteristics and assessment protocol used to assess visuomotor and visual perceptive skill.

After the systematic review conclusion, was done the reflection about the introduction of technology in visuomotor and visual perception assessment. This on presented based on literature-based evidence and clinical practice requirements.

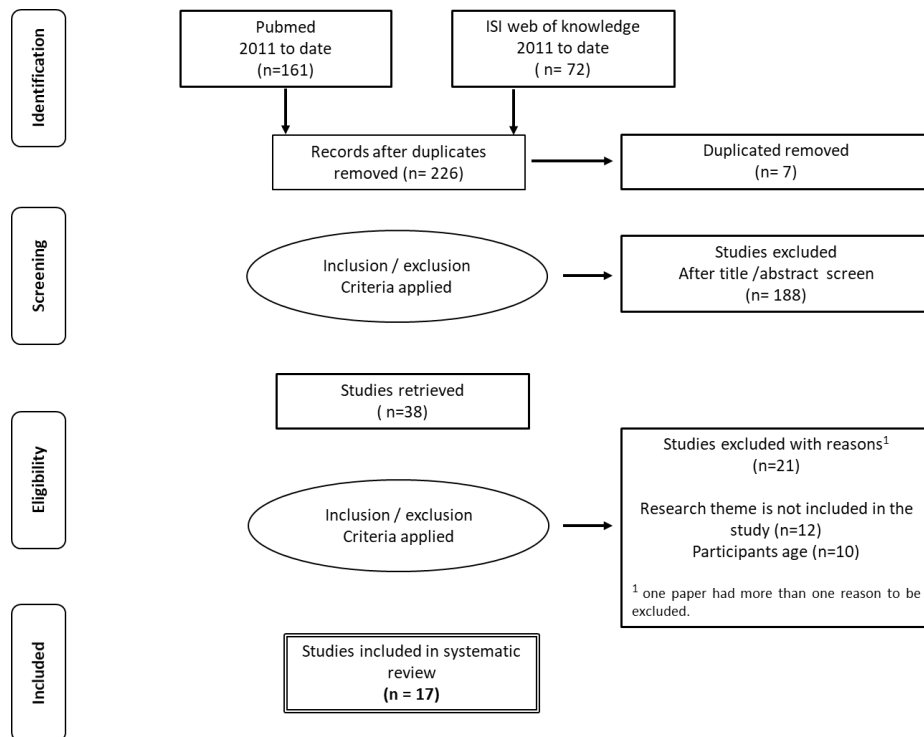


Fig. 1. Literature search strategy (PRISMA flowchart).

4 Results

At the end of the process, 17 articles remain in the inclusion criteria and were enrolled in the analysis (Appendix I). The studies included present mostly a clinical orientation and 12 of them are related to the impact of a specific clinical diagnosis in visuomotor or visual perception skills development / performance. Related to the time perspective to data collected, there was not a clear trend. In this systematic review, 8 transversal

studies, 7 longitudinal and 2 case reports were found. The longitudinal researches are particularly rich on data and follows the children clinical situation during a time period.

It is also important to mention that 5 articles report a phase of a tool development, which leads us to reflect about the necessity for new and more efficient ways to assess children that face clinical and /or developmental issues.

Concerning the assessment tools used, the results were found to be relatively diverse. The Beery-Buktenica Developmental Test of Visual Motor Integration (Beery VMI) is the most commonly used to assess the visuomotor and visual perception skills and were used in 10 studies, as appears in fig 2.

The next most common type of assessment was the Developmental Test of Visual Perception, which was used in 3 studies. The Rey Complex Figure and PreviAs questionnaire were used once each in two studies. As appears in fig 2, more 9 other tools were found, each in their own separate studies.

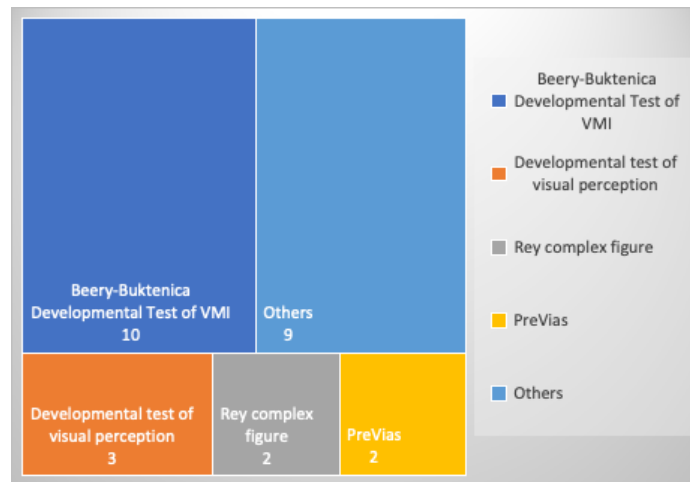


Fig. 2. Tools used for visuomotor and visual perception skills assessment.

The most common situation under study is typical development (n=8) followed by pre term born (n=6), as shown on fig. 3. It is interesting to note that 5 studies have both a clinical group and a control group, which shows us that only 3 studies use subjects with typical development exclusively.

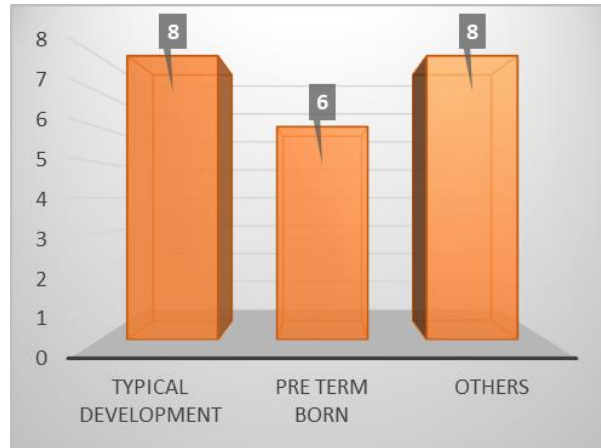


Fig. 3. Development situation under study.

5 Discussion of Results and Critical View

The results show a massive clinical orientation, which highlights the theme importance in clinical practice. Along the same line, the development of new assessment tools emphasizes the necessity for new assessment options in clinical practice. However, when we look at the new tools (Children's Visual Impairment Test, Preverbal Visual Assessment (PreViAs) – parents' questionnaire and Battery for the Evaluation of Visual Perceptual and Spatial processing in children) none of them appears with technological components in its application and/or results analysis. These results are not surprising if we consider that, although healthcare delivery can be improved using health information technology, too few of those systems are implemented and used in developing countries [25].

For example, the PreViAs is a questionnaire delivery to parents on paper and whose analysis requires time and attention. In the same manner, if the health professional reapplies the questionnaire later to reappraise the children's evolution, the data have to be analyzed manually and quick access to the evolution information is not possible. Switching to a digital version, using one of the simple and free solutions available on the market, will facilitate the results analyses and allows an easy follow-up of the patients, monitoring changes quickly and giving information for intervention adaptation.

Surprisingly, among the articles enrolled, no technology was used to accurately conduct the visuomotor and visual perception assessment. Thinking more broadly, increasing technology in diagnosis and treatment will allow big data analyses [26].

As far as the clinical studies are concerned, the Beery VMI clearly appears to be the most frequently used tool. It seems like this instrument is recognized by most of the therapists as the gold standard for visuomotor and visual perception skills assessment. This is a “paper and pencil” tool composed of 3 sub scales: visuomotor integration, visual perception and motor coordination. It takes approximately 30 minutes to apply and another 30 minutes to analyze the results [9]. The time necessary to do that in a proper manner is the highest constraint to use on a large scale in a clinical setting. For this reason, we point the development of a technological solution like VMSreport a possible solution in order to speed up the process [18].

Another aspect that this systematic review highlights is the lack of association of neuroimages and electrophysiological data with the traditional “paper and pencil” tools. The use of a portable visual evoked potential device are progressively introduced in the last years [27-28]. Although these systems are mostly used with screens, so a work to adapt them to instruments like Beery VMI should be done.

The introduction of an eye tracker could be useful to measure the ocular movements during the paper and pencil tests performance. These technological tools are commonly used to assess visuomotor skills in children with cerebral visual impairment [29-31].

The considerable number of longitudinal studies enrolled in this systematic review shows that a large amount of data is available, and that its digitalization should be a priority that can, in the future, improve the analyses and pair the information with artificial intelligence.

6 Conclusion and Further Work

The Beery VMI was the tool most often used to assess visuomotor and visual perception skills in clinical practice. However, it demands a considerable amount of time to score and perform qualitative analyses. For this reason, the development of a tool that automates the process and allows for a longitudinal patient follow-up is recommended. Along these lines, it would be beneficial if all questionnaires were digitalized.

This will allow for quick data collection, without paper and accompanied with the potential benefit of big data analysis. It is also possible to work with other associated technological tools, for example, including the introduction of eye tracker or portable device for electrophysiological signs assessment. The use of portable and/or remote devices is a trend in rehabilitation science and allows the monitoring of patients and their health progression. These generate an extensive quantity of data that could be analysed with different artificial intelligence methods.

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Appendix I - Table 1. Main Characteristics of the studies

Article Author Study type	Population (sample/diagnosis/time assessment)	Instruments used for Visuomotor and Perception Skills assessment
1 Ricci et al., 2014 Longitudinal	n=5, with Dravet syndrome Participants followed between 1 st seizures (± 2 -4 M old) until 7Y, periodic assessment at 2, 4, 6 and 7y.	Atkinson ABCDEFV Battery (2002) - Shape matching (five shape board) - Copying block design The Beery-Buktenica Developmental Test of Visuo-Motor Integration (2000) - Frostig cats' silhouette task Developmental test of visual perception - Form completion and figure ground WISC III (WISC, 2006) - Block design subtest The Rey Complex Figure test - Complex Figure copy
2 Vancleef et al., 2019 Transversal	n=301, between 3 to 6Y old Typical development	Children's Visual Impairment Test - Object recognition, - Degraded object recognition, - Motion Perception Global-Local Processing
3 Vancleef et al., 2019 Transversal	n=59, MA =4y 10Mo Four groups: - typically developing children (MA= 5.1Y) - children with cerebral visual impairment (MA= 4.11 Y) - intellectual impairment (MA=5.0Y) - typical developing but with simulated impaired vision (4.7Y)	The Beery-Buktenica Developmental Test of Visuo-Motor Integration L94 visual perceptual battery
4 Caravale et al., 2011 Longitudinal study	n=26, MA 4Y 11 Mo PTB without major neurological disabilities n=23, MA 5Y, TD	The Beery-Buktenica Developmental Test of Visuo-Motor Integration Developmental test of visual perception Block construction (based on paradigm of Stiles et al. 1996)
5 Lorenzo et al, 2013 Case control study	n= 43, 40 Mo, NF1 children n=43, 40 Mo, TD (the sample and data were included in a longitudinal project)	The Beery-Buktenica Developmental Test of Visual-Motor Integration (5 th Ed.)

Article Author Study type	Population (sample/diagnosis/time assessment)	Instruments used for Visuomotor and Perception Skills assessment
6 Pueyo et al., 2014 Transversal	n=298, between 0.1 to 24 Mo (MA= 11.2 Mo), TD	Preverbal Visual Assessment (PreViAs) – parents questionnaire: - visual attention - visual communication - visual-motor coordination - visual processing
7 Michel et al., 2016 Longitudinal	n=48 children with motor coordination impairment, n=48 TD Describing: n= 18: 4-year-olds n=57: 5-year-olds n=21: 6-year-olds	The Gestalt Closure subtest of the FEW- 2 Developmental Test of Visual Perception
8 Garfinkle et al., 2020 Longitudinal	n=221, 4,5 y, PTB	The Beery-Buktenica Developmental Test of Visual-Motor Integration (6th Ed.)
9 Sanchez Joya et al., 2017 Longitudinal	n=54, assessed between 4 to 5Y: 27 PTB 27 TB	The Rey Complex Figure Test (Rey, 1997)
10 Geldof et al., 2017 Transversal	n=106 PTB assessed at 5,5 y	The Beery-Buktenica Developmental Test of Visual- Motor Integration
11 Willoughby et al, 2014 Case report	n=1, 4Y 1Mo, with 18 deletion syndrome	The Beery-Buktenica Developmental Test of Visual- Motor Integration
12 Linde t al, 2019 Longitudinal	n=167 PT, assessed at 5 and 11Y	Visuomotor and visuospatial functions: - subtests visuomotor precision - assessing graphomotor speed - accuracy Design copying: assessing motor and visual- perceptual skills associated with the ability to copy two-dimensional geometric figures

Article Author Study type	Population (sample/diagnosis/time assessment)	Instruments used for Visuomotor and Perception Skills assessment
13 Schmetz et al., 2017 Transversal	n = 179; 5-14Y TD The subgroup between 5-6 Y n=19 children	Battery for the Evaluation of Visual Perceptual and Spatial processing in children (BEVPS): - visual perceptual object recognition - basic visual spatial processing
14 Verkerk et al. 2014 Longitudinal	n=117, assessed at 3 ½Y and 5½Y, with VLBW but without CP n= 3 ½ Yo, 41 TD CA	The Beery-Buktenica Developmental Tests of Visual-Motor Integration
15 Garcia – Ormaechea et al., 2014 Transversal	n=220; questionnaire applied to parents of children under 2Y	Preverbal Visual Assessment (PreViAs) questionnaire, - visual attention - visual communication - visual–motor coordination - visual processing
16 Veen et al., 2019 Transversal study	n=54 5Y PT; n=28 TB with TD	The Beery-Buktenica Developmental Test of Visual–Motor Integration (6 th ed.) - visual motor integration - visual-perception - motor-coordination -
17 Nicola et al., 2016 Transversal study	n=100 children, from 4 to 14Y, MA= 5,99Y Children with severe specific language impairment	The Beery-Buktenica Developmental Test of Visual–Motor Integration (3rd, 4th and 5th Ed.)

CA- corrected age; MA – Mean age; Mo- Months; PTB- pre term born; TB- Term born; TD- Typical development; VLBW- Very low birth weight; Y–years.