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The development of a screener for Cerebral Visual Impairment

Sara Monteiro[a], Pascale Esch[a], Géraldine Hipp[b] and Sonja Ugen[a]

[a]Luxembourg Centre for Educational Testing (LUCET), Faculty of Humanities, Education and Social Sciences, University of Luxembourg, Esch-sur-Alzette, Luxembourg; [b]Centre pour le Développement des Compétences relatives à la Vue (CDV), Ministère de l'Éducation nationale, de l'Enfance et de la Jeunesse (MENJE), Luxembourg

ABSTRACT

This study explored the secondary use of Luxembourg's school monitoring tool for a large-scale screening of Cerebral Visual Impairment (CVI)-related difficulties. 44 items, with and without time constraint, were developed, and pretested among 959 children. All children subsequently participated in an individual evaluation of higher-level visual processing (HLVP) measures related with CVI. A clinical outcome was attributed post hoc with 32 children being classified as having CVI-related difficulties. To explore the predictive power of the CVI items included in the monitoring, item responses were matched to the results of the individual HLVP assessment. Of all items, the untimed item targeting the combined functions of surface and rotation significantly distinguished group performances (<.05). To improve condition discrimination, different item combinations were tested. Sensitivity and specificity metrics were computed resulting in ranges of 37.5% - 81.3% and 27% - 88.8% respectively. The item combination with the highest sensitivity (81.3%) was retained considering a viable trade-off between sensitivity and specificity metrics. These results support the secondary use of an existing large-scale monitoring tool to screen for CVI-related difficulties in the beginning of elementary school, provided that additional sources of information are progressively implemented to strengthen the tool's predictive power.

KEYWORDS

Cerebral Visual Impairment (CVI); Screening; Large-scale; Higher Level Visual Processing (HLVP); School monitoring; Elementary school

Introduction

The term Cerebral Visual Impairment (CVI) has gathered a lot of discussion within academic and clinical communities, as it typically aggregates a variety of clinical presentations which can affect different levels of visual perception (Ortibus et al., 2011). However, CVI cannot be seen as a "single diagnosis" but rather as a spectrum term comprising different visual deficits depending on the brain area affected and on the extension of damage (Chokron & Dutton, 2023). From a classification and nosology standpoint, CVI is not yet included in any of the classification manuals. A considerable number of studies adopt a CVI classification close to the World Health Organization's designation of visual impairment, which stipulates a level of visual acuity or visual field loss (Chang & Borchert, 2020), and focuses on aspects connected with the ocular domain. However, typical assessments of visual acuity or assessments connected exclusively with the ocular domain can easily miss out on the heterogeneous presentation of CVI (Bennett et al., 2019).

In Luxembourg, as in many other countries in Europe, different state-funded vision screenings are offered on targeted timepoints covering early childhood (up to 3 months, from 3 months to 36 months, and from 3 to 7 years of age). The screenings are not mandatory and mostly include eye measures, such as visual acuity, motility, cover test or color vision (Mazzone et al., 2019). CVI children, however, commonly display visual difficulties that extend beyond functional visual acuity (Chandna et al., 2021; Fazzi et al., 2007; McDowell & Butler, 2023). In other words, not being flagged in these visual screenings does not warrant the absence of CVI as it often implies a discrepancy between fully functional low-level visual processes and impaired higher order processes. To account for this discrepancy, the CVI definition proposed by Sakki et al. (2018, p. 430) following their systematic literature review on terminology was adopted in the context of this study. The authors define CVI as a "verifiable visual disfunction which cannot be attributed to disorders of the anterior visual pathways or any potentially co-occurring ocular impairment." Considering the complexity inherent to CVI, in most countries the absence of a systematic CVI screening implies that children struggling visually risk to be overseen and to be diagnosed only at a much later stage in life (Boonstra et al., 2022). However, an early systematic screening would be particularly important, especially considering that CVI has been shown to negatively interfere with competency areas required to succeed academically, such

CONTACT Sara Monteiro sara.monteiro@uni.lu Luxembourg Centre for Educational Testing (LUCET), Faculty of Humanities, Education and Social Sciences, University of Luxembourg, Esch-sur-Alzette, Luxembourg.

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as reading (Chokron et al., 2021; Gompel et al., 2003), writing (Dutton, 2003) or mathematics (Williams et al., 2011; Monteiro et al., 2023). A late identification of a visually vulnerable profile might entail consequences, as these students are likely to struggle in their educational pathways. The prevalence of CVI-related visual difficulties in mainstream schools has been situated at about 3.4%, which would correspond to around one child in each thirty-children classroom (Williams et al., 2021). Chokron (2008) suggested a general prevalence of around 5% for CVI in school children and hypothesized more specifically that 2 to 3% of 5-year-olds have neurovisual difficulties, i.e., difficulties that may display in visual analysis, visual exploration, visual memory, or in children's capacity to orient their visual attention in space.

It is, thus, commonly accepted that an early diagnosis is crucial for intervention and for the maximization of children's potential, as well as that a lack of consensus and protocols compromise an appropriate identification of children at risk (Boonstra et al., 2022; Fazzi et al., 2009; Morelli et al., 2022). To guide the process of diagnosis, Pilling et al. (2023) suggested a practice protocol for CVI identification based on three main stages of diagnosis comprising the anamnesis, the documentation of visual vulnerability, as well as formal and informal visuo-perceptual testing. As this model is rather comprehensive in nature, and thus requires an in-depth individualized clinical assessment, it is not suitable as a population-based screening. To the best of the authors' knowledge, there is no tool that allows for an initial triage of visual processes in a large-scale group setting. Another issue raised when diagnosing CVI in early childhood is that existing instruments were never originally built for this purpose (Ortibus et al., 2019) and that they were not sufficiently appealing to younger populations, as images and content often fall outside of children's visual repertoire or are semantically charged (Schmetz et al., 2018). Existing tools generally seem to be best fit for an individualized diagnostic process aimed at profiling children's capacities in different neuropsychological domains (Boonstra et al., 2022). These tools are, thus, time and resource consuming and are not suited to be used as a screener. Additionally, the existing neuropsychological tools have not been tested nor normed within the Luxembourgish grade 1 school population under a large-scale administration setting. Other tools, such as questionnaires, are used for population-based screening as they can be particularly efficient to elicit complementary information on children at risk (Pilling et al., 2023). However, to the best of the authors' knowledge, questionnaire use alone does not seem appropriate for the screening of CVI in childhood yet, as the existing tools tend to lack specificity by over identifying positives and thus generating a high number of false positives (Ortibus et al., 2019).

To sum up, considering the prevalence of CVI in early childhood and its impact on academic performance on the one hand, and the constraints of existing diagnostic tools (individual setting and thus time and resource consuming) on the other hand, a phased approach including a systematic large-scale screening seems promising as a first step to be followed by an individual diagnosis (Hokken et al., 2024). The identification of children potentially at risk of CVI would thus precede an in-depth assessment (sustained on multiple normed instruments and clinical expertise) of those children flagged by the screener. Additionally, and as stressed by the Standards for Educational and Psychological Testing "a decision of characterisation that will have a major impact on a student should not be made on the basis of a single test score" (AERA, APA & NCME, 1999, p.146).

Adopting a phased approach, this study aimed to investigate the potential of the well-established Luxembourg school monitoring programme called "Épreuves Standardisées" (ÉpStan) to integrate a systematic nation-wide screener for CVI as early as grade 1. The ÉpStan in grade 1 consists of paper-based standardized competence tests in mathematics, early literacy and listening comprehension, as well as of student and parent questionnaires. As the items of the competence tests aim to reduce the load of language use, especially in mathematics, they are presented in a very graphical and visual way and thus have the potential to be expanded to items specifically developed to screen for CVI.

The development of items that could potentially constitute the CVI screener entailed different phases starting with the choice of a theoretical framework as a reference. As a second step, the items developed to screen for CVI were pretested on a subsample of the grade 1 school population in Luxembourg. These students' behavioral data (i.e., results in the CVI items) was subsequently matched to an individualized neurovisual assessment by experienced practitioners to identify which items should be retained for the large-scale screener and then re-run on the complete cohort of first graders (mean age 7 years old). The development and the large-scale administration setting of these items within the ÉpStan constituted the first attempt at pretesting CVI screening material for Grade 1 children in Luxembourg.

Materials and methods

CVI item generation

Theoretical framework

The CVI item development was initially informed by the theoretical proposal of Schmetz et al. (2018), namely the authors' reformulation of Humphreys and Riddoch (1987) visual perceptual model. Humphrey and Riddoch's (1987) object recognition model includes two main stages, a perceptual one, which allows to build up a correct percept of an object based on visual input, and an associative stage in which there is an association of the elaborated percept with semantic and functional knowledge on objects. Intact object recognition is a skill which is ultimately crucial for functional vision, as daily life and learning depend on perceptual quality, especially of objects (Schmetz et al., 2018). In this sense, Schmetz et al. (2018) set special emphasis on the perceptual stage, a pre-semantic stage, when developing their "Battery for the Evaluation of Visual Perceptual and Spatial Processing" (BEVSP) in children. They reorganized this pre-semantic stage in three levels of early, intermediate, and later analysis, and equally added visual spatial processing to these three dimensions. The early level of analysis includes the mechanisms involved in the processing of elementary shape components, and simultaneous encoding of local and global properties of an object. The intermediate level of

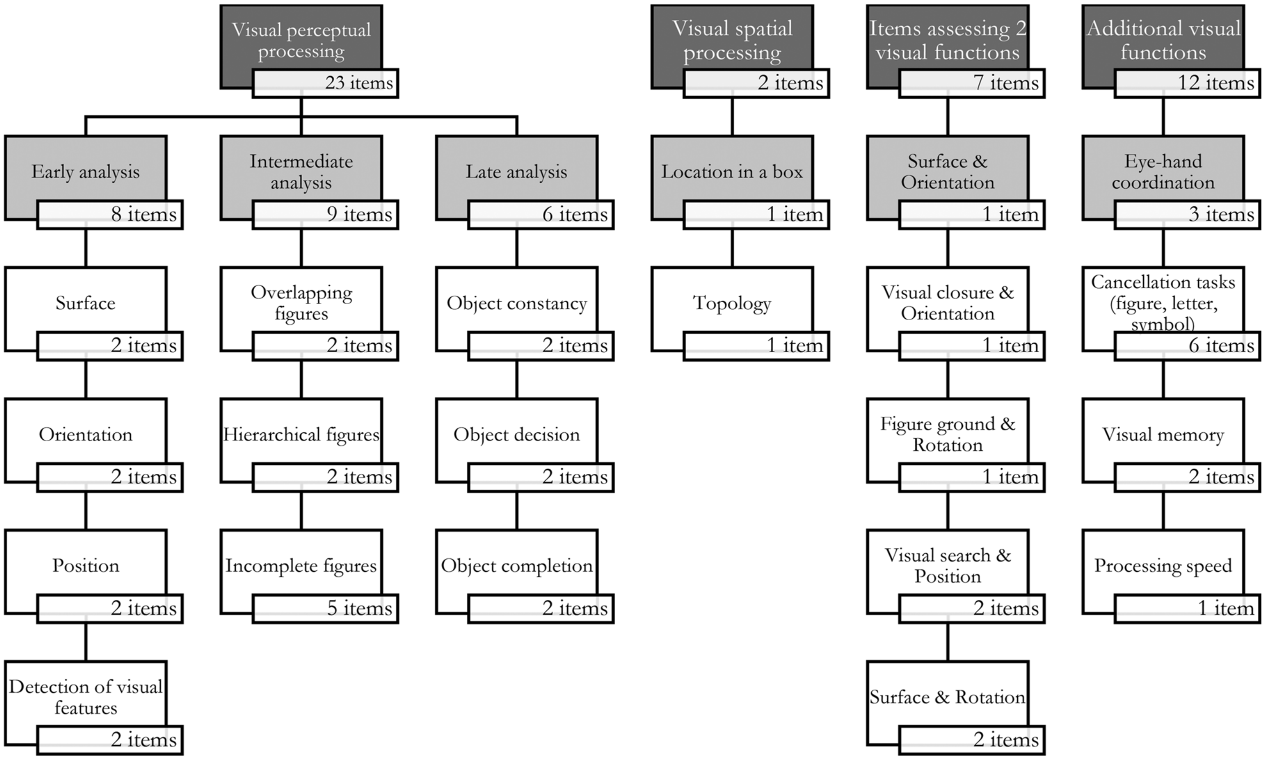

Figure 1. Overview of visual functions included in the screener.

analysis entails the integration of local and global features into a complete and versatile percept of an object. At this level, the processes allow for figure-ground discrimination, visual closure, and the perception of an object independently of its background information. The late level of analysis aggregates pre-semantic aspects and connects them with mnesic object representations. It involves the 3D view-independent elaboration of an object's percept. The processes at this level allow for the match between parts of an object, irrespective of its presentation (e.g., axis, profile, upside down), and long-term memory storage.

Following the model of Schmetz et al. (2018), the development of CVI items to be tested for the screener also implied an early, intermediate, and late level of pre-semantic processing as well as visual spatial processing. In addition, items that simultaneously targeted two visual functions were included to verify if processing more complex visual information would allow to maximize the items' predictive power. The test design further included items that assessed higher-level visual processing which were not sufficiently targeted by the pre-semantic stage of the original model, including items targeting eye-hand coordination, visual attention, visual exploration, and visual memory (focusing on both the dorsal and ventral-stream levels of visual processing). Figure 1 shows an overview of the visual processes to be considered for the initial test design for CVI in the screener's scope.

Considering the relevance of a specific function to visually perform in everyday life, as reflected for example by the higher presence of dorsal stream impairments in childhood CVI (Chandna et al., 2021; Lam et al., 2010; Merabet et al., 2023), an overrepresentation of items addressing those dimensions seemed justified. Nonetheless, the inclusion of items that aim to sample very basic visual perceptual processes were equally included. In total, 44 CVI items were developed, 9 of which were presented with a time restraint. Unless otherwise specified, children had to choose the sole right answer among four options. As a rule of thumb, the items' iconographic information considered the age-range of the children targeted. The images of objects were aimed to fall within these children's repertoire. A comprehensive item rationale and stimuli description are explained below.

Items and stimuli

Visual perceptual processing.

Early analysis.

Surface. Two items were developed to estimate the surface area occupied either by a figurative object (e.g., a fruit) or a geometric Figure (e.g., a circle). Children had to choose the sole right answer among four options. The three distractor options presented different variations in terms of the target surface (namely 15% above target's size, 10% and 15% below target's size).

Orientation. Two items presenting juxtaposing geometric figures evaluated the children's capacity to determine the orientation of objects. The distractors were either placed on a 180° rotation, or with a clockwise or counterclockwise rotation on their vertical axis.

Position. Two items were developed to assess the relative position of an object. Their design was drawn from the Visual Object and Space Perception (VOSP) battery by Warrington and James (1991). Each item presented two grids, a left one containing a Figure (e.g., a chess paw) in one of its cells, and a right one, fully resemblant but empty, without any figure. The participants were asked to mark the position of the object presented in the left grid by drawing a cross on the correct position in the right grid.

Detection of visual features. Two items were developed to target the perception of line orientation. Their guidelines were adapted from Benton's visuospatial line judgment task (Benton et al., 1978). Students had to circle an oblique line (tilted left- or rightwards) among a set of vertical distractor lines.

Intermediate analysis.

Overlapping figures. Two items, one being composed of figurative, and the other of geometric objects, were developed to target children's capacity to distinguish between figure and ground. For each item, a composition of overlapping objects was presented, and participants had to identify which of the 4 answer options was part of the overlapping composition.

Hierarchical figures. Two items were developed to target children's ability to focus on an image as a whole (i.e., targeting visual selective attention at the global level) or on its parts (i.e., targeting visual selective attention at the local level) (Zuidhoek et al., 2015). The items' design was adapted from Navon's (1977) test. For one of the items, a letter was built with small letters. Among four answer options, participants had to identify the letter that corresponded to the whole (and thus disregard the small letters). For the second item, inversely, children had to identify the parts (i.e., the small letters) and disregard the whole.

Incomplete figures. Five items were developed to target children's ability to visually close a degraded or decomposed object, thereby targeting the capacity to complete a whole from the object's parts that are presented. Three of these items presented figurative images, whilst two presented geometric figures. Different item presentations were tested. For the first item the target figure was presented on a black background with a degraded white outline. The four answer options were presented in an undegraded way, also with a white outline against a black background. The second target item was presented with an undegraded black outline against a white background. The four answer options were presented with a degraded white outline against a black background. The third and fourth items were presented on a white background, with degraded black outline. The answer options were also presented on a white background, with an undegraded black outline. The fifth and last target item was presented on a white background with an undegraded black outline. The answer options were presented with a degraded black outline against a white background.

Late analysis.

Object constancy. Two items were developed to target children's capacity to visually recognize objects which are presented from an unusual perspective. The target stimulus provided the image of an object (e.g., a snail). This same object was then displayed in one of the four answer options but from a different angle. Participants were then asked to match the target to its duplicate presented from a different angle.

Object decision. Two items were developed to address the mnesic representation that children have of 3D objects, based on their physical properties. Children were presented with seven drawings of various objects and had to circle the object that did not exist. The fictional objects were composed of parts that belonged to real-life objects but that were not consistent when presented together (e.g., a glass with a fish tail).

Object completion. Two items were developed to address the access to the mnesic structural representation of an object. The target image represented an incomplete version of a familiar object (e.g., a drawing of a car with no wheels). Children were asked to select the missing part(s), based on their knowledge of the object and its parts, to appropriately complete the target object.

Visual spatial processing.

Location in a box. One item was built to target children's capacity to determine the position of individual elements within an overall configuration. A 4×4 grid presented a configuration of coloured-in cells as target. Children were asked to select among four answer options, each presenting 4×4 grids with different configurations of coloured-in cells, the configuration that completely matched the target.

Topology. One item addressed how children distinguish topographical/spatial connections among various interrelated components. A 5×5-pointed grid displayed a set of interconnected lines, which drew a specific pattern in this grid. Children were expected to choose among four possible answer options, each presenting a 5×5 grid with different configurations of interconnected lines, the one identical to the target stimulus.

Additional visual functions. In addition to the adaptation of Humphreys and Riddoch (1987) model by Schmetz et al. (2018), the item development for the CVI screener included items that targeted a set of additional visual functions which mostly covered higher order visual processes included in the model extension presented in the theoretical framework.

Eye-hand coordination (dorsal stream). Based on the Developmental Test of Visual Perception – 2 (Hammill et al., 1993), three items were developed to address eye-hand coordination. These items varied in their level of difficulty. Children had to manually draw a line leading an animal through a path. The first item included a rather spacious straight path, the second item also presented a straight path but tighter in comparison to the first one, and the most difficult item presented a path with motions (i.e., the line was not straight, and a non-linear motion was required to successfully complete the item). The items were presented in a child-friendly manner to increase motivation and comprehension (e.g., mouse must reach the cheese).

Combined visual functions. To potentially increase the screener's predictive power, items that simultaneously targeted two visual functions were added to the above. The following combinations of visual functions were built.

Surface & orientation. Inspired by the subtest "silhouettes" from the Children's Visual Impairment Test for 3- to 6-year-olds (CVIT 3–6) (Vancleef et al., 2020a), the screener included an item that simultaneously targeted surface (i.e., the space occupied by a target figure) and orientation. A figurative target image outlined in black against a white background was presented facing right. Children had to choose which of the 4 black shadows, all of them facing left, matched the target. The surface ratios of the shadows were the same as for the surface item targeting the early level of visual perceptual processing (15% above target's size, 10% and 15% below target's size) presented above.

Visual closure & orientation. Equally inspired by the CVIT 3–6 (Vancleef et al., 2020a; 2020b), an item was developed to simultaneously target visual closure and orientation. The target comprised a figurative black outline drawing of an object against a white background. Four possible answer options were presented, with all of them being oriented in the opposite direction to the target (leftwards). The images of the objects were presented in a fragmented white outline, against a black background. Children had to mentally manipulate the orientation of the objects presented in the answer options, as well as to mentally complete their degraded outline and identify which of them matched the target stimulus.

Figure ground & rotation. Equally informed by the material developed as part of CVIT –-6 (Vancleef et al., 2020a; 2020b), the outlines of four geometric figures were presented in an entangled manner (with black outlines against a white background). The children had to choose among four answer options, which individual figures could be found in the overlapped composition of the target. All four answer options to choose from were oriented leftwards, whereas the target was facing right.

Visual search & position. Two items were developed to address the perception of location. Children were asked to visually analyze a grid and decide on the target's position. These items' design was inspired by an alternative proposal to the VOSP's location task (Warrington & James, 1991), which was suggested by Zuidhoek et al. (2015). A 4×3 grid composed of 11 distractor symbols and one target icon was presented. Children had to choose one of four possible grids, all of them without any symbols, but with a sole red cross representing the position of the target icon. Different positions were presented for each grid.

Surface & rotation. Two items were developed to target surface and rotation. Two shades of geometric figures were presented as targets. Children had to mentally manipulate and rotate these figures to build a new geometrical form. They had to choose the correct composition among a set of four possible answer options.

Cancelation tasks. Six items assessing visual attention and visual exploration were included in the study. Two of these items resembled the letter "A" cancelation task (Corkum et al., 1995), but they did not use the rotation of the target character as distraction stimuli, but other letters from the alphabet which shared visual properties with the target. Both letter cancelation tasks were presented with structured 8×5 grids. In addition, two symbol cancelation tasks were also developed. One of the symbol tasks used the LEA icons (Hyvärinen et al., 1980), also presented in a structured 8×5 grid. The second symbol cancelation task used an unstructured grid, with randomly placed stimuli, not following any pattern. The remaining two items used figurative shades of animals with one item relying on a structured 8×5 grid, whilst the other was presented in an unstructured manner. The design of these cancelation tasks was inspired by the Teddy Bear Cancelation Task (Laurent-Vannier et al., 2006), by the Mesulam Cancelation Task (Weintraub & Mesulam, 1985, 1988) and by the Bells' Cancelation Task (Gauthier et al., 1989). As the grid structure (stimuli displayed in an organized manner vs randomly displayed stimuli) with which cancelation tasks are presented is known to elicit different cancelation strategies and consequently the efficiency with which children complete the task (Wang et al., 2006), the presentation of different cancelation tasks' designs was aimed at testing which grid structure was best to flag CVI children.

Visual memory. The study also included two items targeting the ventral stream by assessing visual memory. First, a target stimulus was shown to the children for a period of 7 seconds. The selected exposure time was based on the guidelines proposed by Zuidhoek et al. (2015). The authors suggested that batteries targeting active recall and recognition should use an exposure period longer than 5 seconds, for children to be able to fully understand the characteristics of the stimuli. After the exposure, the children completed a different item and were then presented a set of four answer options where they had to identify the target previously presented in the exposure phase.

Processing speed measure. A processing speed measure was included as a control measure to investigate whether the quality of visual exploration and visual selective attention within the cancelation tasks was influenced by processing speed. Children had fourteen seconds to cross out thirty fish displayed in three lines of ten fish each.

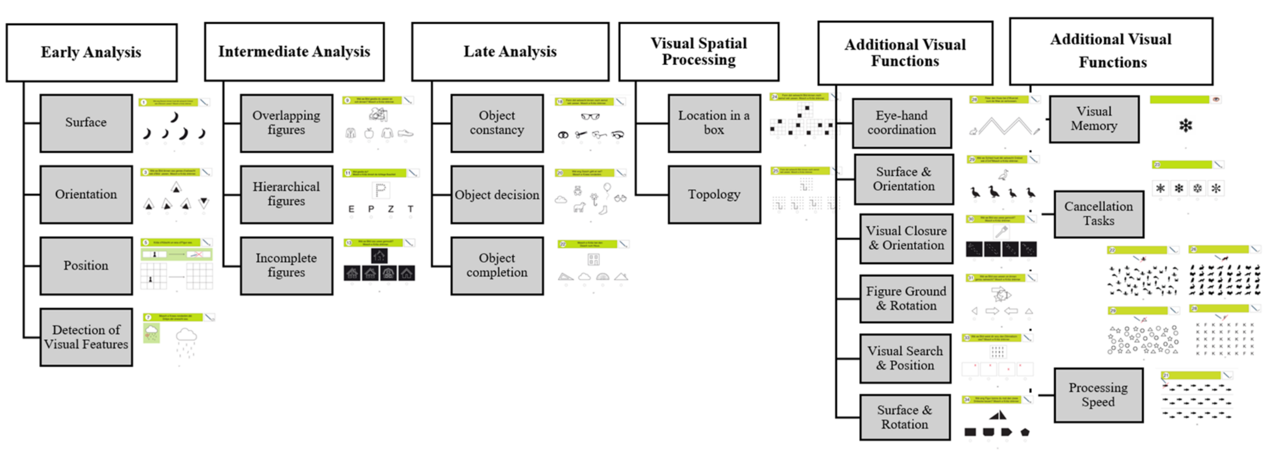

Figure 2. Overview of sample items organized by the visual functions they are designed to assess.

Figure 2 displays an overview of sample items organized by the visual functions they are designed to assess.

Operational framework

The developed CVI items were integrated in the ÉpStan which consists of mandatory questionnaires and standardized competence tests in key academic domains such as mathematics, early literacy, listening and reading comprehension. Every year, the complete student population of grade 1, grade 3 and grade 5 in primary education participate in these large-scale competence tests. Newly developed test content is annually presented as a so-called pretest in a representative sample of the respective grade level to evaluate the feasibility and psychometric quality of the newly developed items before they integrate the main tests of the school monitoring. For grade 1, the tests and questionnaires are presented as A5 paper booklets, and the children answer the items in writing (Fischbach et al., 2014) . Most of the items provide a multiple-choice answer format with one answer representing the correct choice among 3–4 distractor options. The CVI items developed to potentially compose the screener were integrated in different pretest booklets of the school monitoring. The testing time was between thirty and forty minutes per booklet. All CVI items without a time restraint were compiled in a single test booklet where the instructions were read out loud by the teacher, whereas the CVI items that required a timed administration were included in the pretest booklet targeting early literacy, for which the instructions were auditorily presented via streaming. The scoring of non-timed items is done in a dichotomous manner (0 for wrong or missing answer; 1 for correct answer). As missing answers seem to be more prevalent in CVI than neurotypical groups (Chandna et al., 2021), they were coded as a wrong answer, and were included in the computations as they could provide an indication of CVI. The scoring of timed items implied an analysis of raw data rather than a dichotomous approach.

Procedure

The ensemble of the 44 CVI items potentially composing the screener were pretested in a representative subsample of the whole grade 1 school population in Luxembourg.

After participating in the CVI pretest, the children were individually assessed for their higher and lower visual processing skills based on a reference standard, the EVA battery (Cavézian et al., 2010) by a team of specialized practitioners, at school. The data from the individual assessment on the clinical outcome allows to group children in relation to their visual difficulties. A pseudonymised matching of collected behavioral data (i.e., CVI item responses) and the clinical outcome of the subsequent individual assessment allowed to guide the selection of CVI items to be retained for the screener. Ethical Review Pannel approval was not required for this study as it was conducted as part of the national school monitoring programme for which the legal grounds are set by the national authorities. Children and their legal guardians were informed about the inclusion of CVI items within the school monitoring programme and could opt-out before data collection. The Luxembourg school system includes several Competence Centers dedicated to specific missions including learning disorders, language disorders, giftedness, and vision-related disorders. The individual visual assessment done at school by the specialized clinical team is part of the legal mission of the latter. To adhere to European Data Protection Regulations, the data was matched in a pseudonymised manner, through a trusted third party. The trusted third party secured the link between the pseudonym used within the school monitoring (a 4-digit number provided on each test material handed to the student) and the personal data of the students (name, national identification number as well as clinical data). None of the parties had access to this link. More precisely, the data matching was done by the trusted third party and processed by the University team working on the school monitoring data only under the pseudonym. In the same way, the specialized clinical team doing the individualized assessment only had access to the clinical data. Thus, the analyses performed in this study used a pseudonymized dataset.

Selection of a reference standard

Higher-level visual processes. The measure used for the assessment of higher-level visual processes, or visuo-attentional competences, was the Evaluation of Visuo-attentional Abilities (EVA) battery (Cavézian et al., 2010), a rapid test battery which screens for CVI in children aged four to six years old, for which the administration took around twenty minutes. The EVA battery (Cavézian et al., 2010) includes nine subtests focusing on different visual functions. The subtests target gaze fixation, visual field, visual extinction, binocular visual pursuit, visual memory, two cancelation tasks (the teddy bear cancelation task by Laurent-Vannier et al., 2006 and a letter "A" cancelation task by Corkum et al., 1995), an embedded figures task and a matching test. The original norming cohort for this battery consisted of 450 kindergarten children (Cavézian et al., 2010). Considering that approximately 3–5% of children in the general population may have CVI, a 5% threshold was selected to screen effectively for these cases. To analyze performance, the lowest 5% of scores – or the closest value to 5% – from the norming cohort were evaluated separately for each age group (4–5 years and 5–6 years). The total score for each child was calculated by counting the number of subtests they successfully completed (Cavézian et al., 2010). A subtest was considered successful if the performance was above the lowest 5% of scores within the norming cohort, and each subtest received a score of 1 (if successful) or 0 (if unsuccessful). The cutoff score for identifying potential CVI was then determined by the distribution of total scores for the entire battery. For the 5–6-years age group, a child was considered under CVI suspicion if they failed two or more of the nine subtests (Cavézian et al., 2010). However, because the children in this study were older (7–8 years) than those in the original norming sample, stricter cutoffs were applied. This meant that a 7–8-year-old child would be flagged for CVI-related difficulties if they failed just one of the nine subtests. This was a decision made by the clinical team of neuropsychologists, optometrists and orthoptists who individually assess the children at school. If the children performed below the adapted cutoff, the risk for a CVI clinical outcome was attributed to the child.

Low-level visual processes. The optometric and orthoptic measures included an assessment of monocular visual acuity for far vision (left and right eye), binocular visual acuity for near vision, binocular low contrast sensitivity (in near vision) by using the LEA symbols optotypes (Hyvärinen et al., 1980), a color vision assessment (Ishihara, 1917) as well as a binocular vision assessment including a convergence test, namely Punctum Proximum de Convergence (PPC), a cover test, ocular motility, and stereo acuity (stereopsis). The assessment took around ten minutes. The combination of these measures was used to identify children who were at risk of ophthalmological difficulties, or who displayed difficulties with low-level visual processing.

Participants

The study's sample included 959 children (53.70% girls) who were representative of the whole grade 1 student population of Luxembourg in terms of gender and socio-economic status. This sample was divided into children (N = 463) participating in the non-timed items (54.31% girls) and children (N = 494) participating in the items with a time restraint (53.15% girls). These children were tested twice, once as part of the large-scale school monitoring programme, and another time for higher and lower visual processes during an individualized session held at school, done by a team of specialized practitioners. Of the 959 children participating in the CVI items' pretest, 755 were considered Typically Developing (TD) as they did not struggle in any of the visual measures collected by the reference standards, regardless of whether these addressed lower- or higher-level visual processing. 32 children were flagged by the EVA battery targeting higher-level visual processes (Cavézian et al., 2010) and thus classed as CVI group. 162 children struggled in the measures targeting low-level visual processes and were thus classed as the ophthalmological group. Finally, 10 children were found to have difficulties in both, low- and higher-level visual processes and were, therefore, classed as having a combination of CVI and ophthalmological difficulties.

Table 1 displays the distribution of the pretest sample per clinical outcome, as well as demographic information on age and gender. Table 2 displays a comprehensive sample distribution on the non-timed and timed items.

Results

Data management and analyses were made using the Statistical Software for Social Sciences (version 27.0.0.0).

Confirmation of the reference standard

As developed in the methods section, the combination of EVA battery's subtests (Cavézian et al., 2010) was used to identify children with CVI within the grade 1 school

Table 1. Distribution of the pretest sample per clinical outcome.

	TD (*n* = 755)	CVI (*n* = 32)	Ophtha (*n* = 162)	CVI & Ophtha (*n* = 10)	Total
Age (months/SD)	84.04 (5.23)	86.11 (4.44)	84.14 (5.87)	87.39 (8.37)	–
Male/female ratio (*n*)	176/203	7/9	40/46	2/3	486

TD = Typically developing; CVI = Cerebral Visual Impairment; Ophtha = Ophthalmological.

Table 2. Distribution of the pretest sample on the non-timed and timed items.

	TD	CVI	Ophtha	CVI & Ophtha	Total
Non-timed items (*n*)	361	13	87	2	463
Age	81.92 (5.32)	85.19 (5.06)	81.80 (5.73)	77.47 (.98)	–
Male/female	83/91	4/5	19/28	NA/2	232
Timed items (*n*)	394	19	75	8	494
Age	85.99 (4.32)	86.75 (3.99)	86.85 (4.79)	89.87 (7.40)	–
Male/female	93/112	3/4	21/18	2/1	254
Total	755	32	162	10	959

TD = Typically Developing; CVI = Cerebral Visual Impairment; Ophtha = Ophthalmological.

Table 3. Mean performance and standard deviation of the EVA battery's subtests (Cavézian et al., 2010) presented by group.

	TD (*n* = 890)		CVI (*n* = 38)		
Subtest	*M*	*SD*	*M*	*SD*	Welch's t-test
Visual Field (12)	11.99	.12	11.24	2.75	*n.s.*
Gaze fixation (1)	.96	.19	**.63**	.49	***
Gaze extinction (1)	1	.06	.92	.27	*n.s.*
Visual pursuit (3)	2.89	.36	**2.39**	.92	*
Visual memory (4)	3.71	.52	**3.39**	.79	*
Teddy Bear CT (15)	14.94	.26	**14.50**	.76	**
Letter A CT (15)	14.0	1.14	**12.11**	2.13	***
Embedded figures (23)	22.09	1.60	**20.39**	3.19	**
Matching (8)	7.94	.29	7.66	.97	*n.s.*

For each subtest, the maximum score is indicated between brackets.
Note: *p <.05; **p<.01; ***p<.001.

Table 4. Mean percentage of correct responses and standard deviation for non-timed items targeting single and combined visual functions, presented by group.

	Typically developing ($n = 361$)		CVI ($n = 13$)			
Visual perceptual processes	*M*	*SD*	*M*	*SD*	*Fisher's exact test*	χ^2
Early Level						
Surface (*item 1*)	58.4	49.3	46.2	51.9		*n.s.*
Surface (*item 2*)	65.4	47.6	46.2	51.9	*n.s.*	
Orientation (*item 1*)	**96.7**	18	**100**	0	*n.s.*	
Orientation (*item 2*)	**97**	17.2	**100**	0	*n.s.*	
Position (*item 1*)	80.3	39.8	76.9	43.9	*n.s.*	
Position (*item 2*)	73.4	44.2	84.6	37.6	*n.s.*	
Detection of visual features (*it. 1*)	**97**	17.2	**100**	0	*n.s.*	
Detection of visual features (*it. 2*)	**97.8**	14.7	**100**	0	*n.s.*	
Intermediate Level						
Overlapping figures (*item 1*)	70.9	45.5	76.9	43.9	*n.s.*	
Overlapping figures (*item 2*)	92.2	26.8	92.3	27.7	*n.s.*	
Hierarchical figures (*item 1*)	**98.3**	12.8	**100**	0	*n.s.*	
Hierarchical figures (*item 2*)	55.1	49.8	46.2	51.9		*n.s.*
Incomplete figures (*item 1*)	88.1	32.4	92.3	27.7	*n.s.*	
Incomplete figures (*item 2*)	**98.9**	10.5	**100**	0	*n.s.*	
Incomplete figures (*item 3*)	83.9	36.8	69.2	48	*n.s.*	
Incomplete figures (*item 4*)	87	33.7	92.3	27.7	*n.s.*	
Incomplete figures (*item 5*)	60.7	48.9	46.2	51.9	*n.s.*	
Late level						
Object constancy (*item 1*)	**97.5**	15.6	**100**	0	*n.s.*	
Object constancy (*item 2*)	**98.1**	13.8	**100**	0	*n.s.*	
Object decision (*item 1*)	88.1	32.4	92.3	27.7	*n.s.*	
Object decision (*item 2*)	91.1	28.5	92.3	27.7	*n.s.*	
Object completion (*item 1*)	**98.6**	11.7	**100**	0	*n.s.*	
Object completion (*item 1*)	**99.2**	9.1	**100**	0	*n.s.*	
Visual Spatial Processing						
Location in a box	**95**	21.8	92.3	27.7	*n.s.*	
Topology	88.6	31.8	69.2	48	$p = .058$	
Additional visual functions						
Eye-hand coordination (*item 1*)	92.8	25.9	84.6	37.6	*n.s.*	
Eye-hand coordination (*item 2*)	93.6	24.5	84.6	37.6	*n.s.*	
Eye-hand coordination (*item 3*)	92.8	25.9	76.9	43.9	*n.s.*	
Combined visual functions						
Surface & orientation	43.2	49.6	23.1	43.9		$p = .049$
Visual closure & orientation	**96.4**	18.7	**100**	0	*n.s.*	
Figure ground & rotation	91.7	27.6	92.3	27.7	*n.s.*	
Visual search & position (*item 1*)	94.7	22.4	92.3	27.7	*n.s.*	
Visual search & position (*item 2*)	92.8	25.9	76.9	43.9	*n.s.*	
Surface & rotation (*item 1*)	29.4*	45.6	0*	0	$p = .02$	
Surface & rotation (*item 2*)	73.7	44.1	61.5	50.6	*n.s*	

Group differences were tested using Pearson chi-square and Fisher's exact test.
Note. Numbers in bold represent sub-sample's scores which are above ceiling (>=95% of correct answers); *p <.05.

population of Luxembourg. Table 3 presents the mean performances in the EVA battery's subtests per group with Welch's t-tests exploring mean differences between TD and CVI groups. As can be verified in Table 3, there were significant subsample differences in all items except for visual field, gaze extinction and matching. As a result, the EVA battery was confirmed as the reference standard against which the CVI items were assessed in their fundamental screening metrics (Trevethan, 2017).

The following section will present the different stages of setting up a CVI screener which would be applicable at large-scale level and allow for a first triage of children at risk within the grade 1 population.

Selection of items to be retained for the CVI screener

Table 4 presents the mean percentage of correct responses and standard deviations for the non-timed items targeting single and combined visual functions. First, following a procedure implemented by Schmetz et al. (2018), items with a percentage of correct answers above or equal to 95% in the CVI group were excluded as ceiling effects reveal a lack of item's sensitivity to identify the condition. This is particularly important to select items for the scope of a screener, considering that the retained items should allow inferences regarding group membership (Schmidgall et al., 2017). When both samples reveal similar response patterns, it becomes difficult to discern group membership as there is little variability in the data, and particularly between groups (Uttl, 2005).

11 out of 35 non-timed items presented ceiling effects (Table 4). This was the case for the items targeting orientation, for items targeting the detection of visual features (i.e., item detecting the perception of line orientation), for item 1 of hierarchical figures, for item 2 of incomplete figures, for items targeting object constancy and object completion as well as for the item on visual closure and orientation, all of which ceiled across groups, regardless of classification. As a result, these items were not retained for the CVI screener. A significant group difference was found for the item assessing the combined functions of surface and rotation ($p < .05$; with Fisher's exact test) with the full CVI subsample failing to provide a correct answer on this item (as opposed to 29% of correct answers among TD children). The item presented

two shades of geometric figures which children had to mentally manipulate and rotate to build a new geometrical form. A marginally significant difference was found for the item combining the visual functions of surface and orientation ($p = 0.49$) suggesting a tendency of this item to distinguish between groups. Similarly, the item targeting topology yielded a marginally significant group difference with Fisher's exact test ($p = 0.58$).

Table 5 presents the mean score of correct responses and standard deviations for timed items. Regarding the timed cancelation tasks presented in Table 5, the results revealed high performances on all tasks and across subsamples, with the mean score of correctly marked targets being close to their ceiling value of 10. No significant differences were found between TD and CVI subsamples, neither for correctly marked targets nor for distractors. Indeed, except for the octopus cancelation task, the CVI subsample did not mark any distractors. Similarly, no significant mean differences were observed for the item evaluating processing speed.

Table 5. Mean of correct responses and standard deviations for timed tasks presented by group.

	TD ($n = 393$)		CVI ($n = 19$)		
Cancelation task	*M*	*SD*	*M*	*SD*	*t-test*
Octopus					
Total targets	8.02	3.20	8.32	2.75	*n.s.*
Total false alarms	.92	3.6	.26	.65	*n.s.*
LEA Symbols					
Total targets	8.7	2.70	8.58	2.09	*n.s.*
Total false alarms	.47	3.07	0	0	*n.s.*
Letter A					
Total targets	9.31	2.03	8.8	2.79	*n.s.*
Total false alarms	.17	2.08	0	0	*n.s.*
Fox					
Total targets	8.57	2.28	8.26	2.75	*n.s.*
Total false alarms	.13	1.61	0	0	*n.s.*
Letter F					
Total targets	9.02	2.16	8.84	2.19	*n.s.*
Total false alarms	.22	2.29	0	0	*n.s.*
Symbol					
Total targets	9.28	1.94	9.16	2.22	*n.s.*
Total false alarms	.07	1.27	0	0	*n.s.*
Control measure					
Processing Speed	12.74	9.46	11.68	9.49	*n.s.*
	M	*SD*	*M*	*SD*	*Fisher*
Visual memory					
Item 1	87.9	33	72.2	46	*n.s.*
Item 2	91.5	28	77.8	43	*n.s.*

Group differences were tested using two-tailed independent t-tests and Fisher's exact test for the visual memory items.
TD = Typically Developing; CVI = Cerebral Visual Impairment.

Computation of retained CVI items' metrics

To evaluate the predictive power of the retained item on surface and rotation, the following parameters were considered (Trevethan 2017):

$$Sensitivity = \frac{TP}{(TP + FN)} * 100$$

$$Specificity = \frac{TN}{(FP + TN)} * 100$$

$$Positive\ Predictive\ Value\ (PPV) = \frac{TP}{(TP + FP)} * 100$$

$$Negative\ Predictive\ Value\ (NPV) = \frac{TN}{(FN + TN)} * 100$$

Accordingly, the item on surface and rotation, which significantly distinguished between groups, had a sensitivity of 100% meaning that all the children who have the condition according to the reference standard failed this item. The specificity was around 27%, meaning that 27% of the children identified as not having the condition by the reference standard correspond to true negatives whereas around 73% were false positives. The item's positive predictive value was set at 5%, which means that of all the children who failed to successfully complete this item, only 5% constituted true CVI children, whereas the negative predictive value was set at 100%, which translates into full confidence that children who successfully answered this item belonged to the TD group and did not have the condition. However, from a practical perspective, the number of false positives resulting from the sole use of this item (around 70% of the grade 1 school population) cannot be considered an appropriate option as it would imply an extremely high demand for a subsequent individual clinical assessment of these flagged children. To minimize the number of false positives prompted by using a single item, the pool of non-timed items was explored to compute these predictive power values for selected item combinations including the item on surface & rotation. Considering that there were no other items with significant group differences, the combinations targeted items for which the accuracy discrepancies between groups were the largest (i.e., bigger than 10%). Table 6 displays

Table 6. Selected item combinations and corresponding sets of sensitivity, specificity, and predictive values at zero cutoff.

	Item combination	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
1	Surface & rotation *item 1 – used in isolation*	100	27	5	100
2	Surface & rotation *item 1* + surface *item 1*	62.5	63.6	6.5	97.7
3	Surface & rotation *item 1* + surface *item 2*	62.5	70.1	7.8	97.9
4	Surface & rotation *item 1* + hierarchical fig. *item 2*	62.5	62.3	6.3	97.6
5	Surface & rotation *item 1* + incomplete fig. *item 3*	43.8	88.8	8.2	97.2
6	Surface & rotation *item 1* + incomplete fig. *item 5*	62.5	65.1	6.8	97.7
7	Surface & rotation *item 1* + topology	43.8	82.8	9.3	97.3
8	Surface & rotation *item 1* + eye-hand coordination *it3*	37.5	86.1	9.8	97.1
9	Surface & rotation *item 1* + surface & orientation	81.3	57.5	7.2	98.7
10	Surface & rotation *item 1* + visual search & position *it2*	37.5	86.1	9.8	97.1
11	Surface & rotation *item 1* + Surface & rotation *item 2*	50	75.7	7.7	97.4

PPV = Positive predictive value; NPV = Negative predictive value.

different item combinations, considered at a zero cutoff (i.e., children needed to fail both items).

The different item combinations that were tested displayed NPV values ranging from 97–100%. The metrics for sensitivity and specificity showed more variation with a dynamic negotiation between these two metrics resulting from the fact that increasing one of the metrics implied a drop on the other (Table 6). Increasing specificity translates into reducing the number of false positives which would decrease the challenge on the health system (option 8 or option 10 of Table 6) whereas improving sensitivity would strengthen the detection of CVI but on the cost of the care system (option 1 of Table 6). Considering the alternatives that were explored and presented on Table 6, option 9 representing the item combination of "surface and rotation" together with "surface and orientation" with a sensitivity of 81.3% and a specificity of 57.5% seemed to be the most appropriate to be retained as a screening tool at large-scale level.

Discussion

This study aimed to investigate the potential of the existing large-scale school monitoring programme in Luxembourg to integrate items that have been specifically developed to screen for CVI in young children (grade 1). The item development process was based on the extension of Humphreys and Riddoch's model (1987), done by Schmetz et al. (2018), and further extended by other visual functions such as eye-hand coordination, visual memory, visual selective attention, visual exploration, as well as items comprising two visual functions simultaneously. Altogether 35 non-timed items and 9 timed items, including a processing speed control measure, were developed. The timed items were administered to a representative sample of 413 grade 1 children, whereas the non-timed items were administered to a second representative sample of 374 grade 1 children. As a second step, the children who participated in the pretest of the CVI items were individually tested for CVI with the EVA battery (Cavézian et al., 2010) as the reference standard. The results of the CVI items were then matched with the results on the individual EVA battery to explore large-scale CVI item retention and related metrics. With regards to the EVA, this study's results differ from the battery's validation study (Cavézian et al., 2010), where the Letter A cancelation task was the only item without a significant group effect. Even though the subtests' discrimination capacity differs across the validation and this study's sample, the tool's capacity to explore CVI is confirmed, as can be verified on Table 3. Additionally, to the extent of the authors' knowledge, the EVA battery represents the only non-digital CVI assessment tool validated for population use. From a practical perspective, the rather short administration time of the EVA battery was considered for feasibility as it allows to minimize the strain on the specialized professionals who need to apply the battery to the whole pretest sample of 959 children.

First, items which ceiled across groups (accuracy rates above 95%) were excluded. Consequently, all timed items proved to be too easy in their current design, including the processing speed item which was initially conceived as a control measure for the selective visual attention items, confirming that the number of canceled targets within the cancelation tasks was related to attentional performance rather than speed. Overall, considering the operational framework of the screener i.e., a large-scale format of group administration, it can be concluded that the timed items were not appropriate in terms of design and level of difficulty to differentiate between the two groups, and potentially be retained for the screener. A possible explanation for these ceiling effects might relate to the paper-based administration format of the timed items. More specifically, considering the visual memory items, the supervised group administration did not allow to entirely control for children going back in the booklet and revisiting the target stimuli to confirm the correctness of their answers, thus defeating the purpose of the item, and compromising its validity. The same ceiling effect was found in the cancelation tasks, regardless of their grid structure (organized versus disorganised) and stimuli presentation (symbolic versus figurative). The time allocated to the administration of these items was probably not sufficiently limited, and their level of difficulty or format of administration was not adequate to discriminate difficulties in visual attention and visual exploration within this age range. Again, the large-scale group setting might not have been suitable for this type of items as they had rather proven their validity in individual test settings (Corkum et al., 1995; Gauthier et al., 1989; Laurent-Vannier et al., 2006; Wang et al., 2006; Weintraub & Mesulam, 1985, 1988). Further research should address whether the absence of group differences between TD and CVI children relates to the items' design or rather to the large-scale group setting of test administration.

Within the pool of non-timed items, the item targeting "surface and rotation" seemed to have the strongest predictive power to identify children with CVI and it was further used to calculate the metrics of a screener. The items targeting "surface and orientation" as well as "topology" also showed marginal significance for group distinction. A major challenge consisted in suggesting an appropriate threshold for the CVI screener's specificity and sensitivity metrics as the respective consequences of under- or over identification of children at risk need to be addressed (Trevethan, 2017). Opting for a screener with high sensitivity will also entail a high number of false positives whereas, inversely, increasing specificity will also raise the share of false negatives. And, as (Mallett et al. (2012) pointed out, dealing with false positives and false negatives is very rarely equivalent. Thus, it is inevitable to consider a tradeoff between the sensitivity and the specificity of a screening tool as these inversely relate, with an increase in one being followed by a decrease of the other (Parikh et al., 2008). Considering that CVI has been proven to deleteriously interfere with key academic competences such as reading (Chokron et al., 2021), writing (Dutton, 2003) and mathematics (Williams et al., 2011), an early diagnosis followed by an early intervention is crucial for preserving the children's potential for academic success (Chang & Borchert, 2020; Chokron & Dutton, 2016; Molloy et al., 2017). Thus, leaving CVI symptoms unidentified (i.e., accepting an increase in false negatives) will not come without consequences. On the other hand, the CVI item that yielded the most significant differences in results between CVI and TD children, thus resulting in the highest sensitivity, equally entailed a very high number of false positives which is not sustainable from a health service perspective. To tackle this challenge of tradeoff, different combinations of the item "surface and rotation" and other individual items with accuracy discrepancies equal or above 10% between CVI and TD children, were explored at a more stringent threshold (i.e., children needed to fail both items). For each of the item combinations, the fundamental metrics in terms of sensitivity (i.e., the test's ability to identify an individual having the condition), specificity (i.e., the test's ability to identify an individual not having the condition), PPV (i.e., the percentage of individuals identified as positive by the screener that actually have the condition) and NPV (i.e., the percentage of individuals with a negative result in the screener that do not have the condition) were calculated (Parikh et al., 2008).

Furthermore, when addressing this tradeoff, prevalence rates need to be considered as they have a strong impact on the above-mentioned screener metrics. More precisely, a low prevalence rate will directly imply a low PPV and in the same way, higher population prevalence rates will display in lower NPVs (Parikh et al., 2008). Previous research (Williams et al., 2021) provided a low prevalence rate of 3.4% for CVI-related visual difficulties among primary school children. This result was confirmed for grade 1 children in Luxembourg with a prevalence rate of 3.4% (Author, 2023). Exploring the prevalence rate of a condition in a specific population is indeed an important factor to consider in the metrics' expectations of a screening tool (Akobeng, 2007). As 96% of grade 1 target population in Luxembourg are expected to be TD children (Monteiro et al., 2023), the NPVs for CVI would also be higher as this metric translates the probability of not having the condition. This hypothesis was confirmed for all item combinations. Opting for the item combination "surface and rotation" jointly with "surface and orientation" will imply a higher CVI sensitivity to the cost of a lower specificity, which in turn will entail a heavier load on the health care system during this initial phase of developing, testing, and adapting the screening tool in exchange for a lower share of false negatives. A higher share of false positives is a misdiagnosis cost considered acceptable for this stage of development of the screener, knowing that stringency can be adjusted with future alterations of the tool (Trevethan, 2017). Accepting a higher number of false positives inherently increases the proportion of true negatives correctly identified (Trevethan, 2017). From a service perspective, this approach corresponds to entirely fulfilling their mission of identifying CVI children considering that the inclusion of falsely flagged individuals is counterbalanced by reducing the number of CVI children that may have otherwise been overlooked (i.e., false negatives). This consideration is particularly critical and ethically preferable when considering the well-documented negative impact of CVI on academic performance, with consequences manifesting as early as the onset of grade 1 education (Chokron et al., 2021; Chokron & Dutton, 2023; Molloy et al., 2017; Monteiro et al., 2023; Williams et al., 2011).

Parikh et al. (2008) described a similar constraint for the screening of angle closure glaucoma, a condition that also shares a low population prevalence of 3%. The authors suggested that for conditions with such a low prevalence rate, an adequate strategy of screening would rely on considering more data sources. With the goal to continuously strengthen the predictive power of the CVI screener, the option of considering questionnaire-based data in addition to the CVI items would provide a promising outlook to potential adaptations of the tool. It is, however, important to re-emphasize that none of the CVI items were interpreted on their own nor resulted in a final high-stake decision but, with the aim of providing a screening, they allowed for a first triage of grade 1 children to be eligible for a subsequent individual clinical testing that will, then, provide more informed decisions. In this sense, the metrics of the CVI screener confirmed the idea that no tool seems to suffice in isolation for the diagnosis of CVI (Ortibus et al., 2019; Pilling et al., 2023) ; and that, considering the variety of clinical profiles as well as the low prevalence rate of this condition, a multi-step approach to diagnostics is highly advisable (Hokken et al., 2024).

Conclusions and limitations

A few limitations to this study need to be considered. Using the EVA battery as the reference standard may risk missing out on CVI profiles that result from other visual perceptual processes than selective visual attention and visual exploration as these constitute the focus of the EVA battery. This may hold for visual perceptual processes that were deemed frail based on the CVI screener item "surface and rotation" as this item implies visual processes that are not sufficiently represented in the different subtests of the reference standard. These children might, therefore, have been classified as TD and subsequently considered as false positives resulting from the screener when, in fact, their visual perceptual difficulties result from processes that are not sufficiently covered by the reference standard. However, to the extent of the authors' knowledge, no other diagnostic tool offers such a wide and efficient range of visual perceptual testing at population level, without requiring the use of additional resources, such as computer-based or electronic devices. It is also worth mentioning that the validation sample for the EVA battery (Cavézian et al., 2010) used a part of the CVI spectrum that is closer to its severeness (i.e., children were already known to health services, being the CVI group built with children who were followed in a neurology service) which entails more condition manifestations than a random population sampling. This kind of validation sampling can have an impact on the sensitivity and specificity, as it addresses a part of the spectrum of the disease which tendentially displays more symptoms and therefore encompasses an easiness of diagnosis (Parikh et al., 2008). The number of false positives that the screener prompts is an aspect that will likely entail future tool adjustments and that may be perceived as a study limitation. Nonetheless and, as Trevethan (2017) mentions, screening tools are prone to imperfections, and it is within their very nature to continuously require adjustments on stringency or leniency according to adjacent sources of data or system requirements. Furthermore, developing screening tools for conditions with such low prevalence as the one CVI has is challenging when sampling is done at population level, as it was the case in this study. This is mostly because the manifestations of the clinical condition are normally subtler at population level than in settings where sampling is hospital-based and where the condition tends to be severer (Parikh et al., 2008).

This study's sample size may constitute a study limitation. However, the children who participated in this study constituted a representative sample of the whole grade 1 school population of Luxembourg in terms of both gender and socio-economic status. These characteristics support, to an extent, the representativeness to the target population. In addition, the prevalence for CVI risk as detected within our sample aligns with internationally reported rates, which range between 3.4% and 5% (Chokron, 2007; Williams et al., 2021). Even though the generalizability of our findings should be approached with caution, the congruence of prevalence rates suggests that our findings reflect patterns that were observed in similar populations.

Considering that existing literature remains inconclusive regarding the potential of imaging techniques to reliably detect CVI (Dutton, 2015; Fazzi et al., 2015; Lueck & Dutton, 2015; Lueck et al., 2023; Pilling et al., 2023), this study refrained from including these techniques (e.g., MRI) to corroborate the data obtained. However, children who were identified as potentially having CVI through the reference standard were invited for a second assessment. This assessment aimed to determine whether the difficulties identified through the EVA and the visual tasks of the screener were supported by additional neuropsychological tools.

The findings of this study suggest that timed items do not seem to provide an effective measure for identifying CVI in a large-scale pen-and-paper group assessment setting. Considering that recent research revealed the use of digitalized tools as a promising potential to detect CVI detection, particularly through the collection of reaction time data (Hokken et al., 2023; 2024; Merabet et al., 2023), future research would be needed to explore if these digitalized tools could provide an alternative for a large-scale group assessment. For the near future, as the national school monitoring will not be able to rely on digital tools for test administration in grade 1, this potential adoption should remain under consideration. Another important aspect to highlight concerns the broad range of visual functions targeted by the non-timed items. Although most visual functions were assessed by only two items, which represents a limitation to the construct's comprehensiveness, it is important to note that profiling children was not the primary objective of this screening tool. Consequently, future adaptations of the screener should focus on the development of additional items that address the visual processes shown to be the most effective in potentially identifying CVI, more specifically those that are involved in completing tasks that require the manipulation of surface and rotation. These future amendments are expected to improve both the tool's screening metrics as well as its psychometric properties.

This study's results also provide important information pertaining to whether there are gains to use a large-scale school monitoring tool for screening purposes. In fact, a similar conclusion has already been drawn in terms of low-level visual processing assessments, namely the fact that the use of structures that are already implemented constitutes an add on from a resource and efficiency perspective (McConnell et al., 2021). Indeed, this study suggests that there also seems to be added value in using the available resources that are fully implemented at population level for secondary purposes. On one account, using a tool already set in place, developed with age-appropriate material and with which children and their families are familiarized is an important factor in engagement. On a second account, using this same large-scale tool allows to address a part of the population that had previous access to low-level visual processing screenings as part of the ongoing Luxembourgish visual assessments (Mazzone et al., 2019) but that did not have access to a higher-level visual processing assessment. From a health access perspective this is a very important gain. On a third account, CVI is known to have a negative impact on children's educational success (Chokron et al., 2021; Chokron & Dutton, 2023; Williams et al., 2011). Simultaneously it is also a condition that is known to be under diagnosed, in part due to the way compensation strategies are so well incorporated in children's behavioral repertoire (Philip and Dutton, 2014) that they become almost imperceptible to the children themselves and to the caregivers. Therefore, the systematicity of a screening is, undoubtedly, an important step to prevent that children who struggle visually from being left unseen.

Lastly, to the extent of the authors' knowledge, no large-scale monitoring tool, similar to the developed for the school context of Luxembourg, has ever been used for secondary CVI screening purposes with grade 1 children. Furthermore, the study's findings confirm the potential of an existing test infrastructure such as a standardized school monitoring tool to integrate a preliminary triage of children at risk of CVI. This insight may be generalized to different school systems or countries with an established school monitoring programme in place which would allow to integrate tasks that target visual processes linked to CVI. This is particularly promising when considering that the possibility of extending a CVI screening to a national scope is an important step to ensure equality of children's access not only to health (from a visual standpoint) but equally educationally (from a functional adaptation perspective, in the event of CVI identification). This paper does not absolve the screener from improvements, but it represents an important step in terms of the potential of large-scale monitoring tools' use for CVI screening nationally and internationally to ensure better access to health and education in childhood.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Sara Monteiro http://orcid.org/0009-0002-6759-714X
Pascale Esch http://orcid.org/0000-0002-0892-9960
Géraldine Hipp http://orcid.org/0009-0002-0037-6887
Sonja Ugen http://orcid.org/0000-0002-0174-8091

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