Diagnostic Performance and Repeatability of a Novel Game-Based Visual Field Test for Children

Tariq Mehmood Aslam,1,2 Zaria Christine Ali,1 Yanfang Wang,2 Cecilia Fenerty,1 Susmito Biswas,1 Emmanouil Tsamis,2 and David Barry Henson1,2

1Manchester Royal Eye Hospital, Manchester University NHS Foundation Trust, Manchester Academic Health Science Centre, Manchester, United Kingdom
2School of Pharmacy and Optometry, Faculty of Biology, Medicine and Health, University of Manchester, Manchester, United Kingdom

Correspondence: Tariq Mehmood Aslam, Manchester Royal Eye Hospital, Oxford Road, Manchester M13 9WL, UK; tariq.aslam@mft.nhs.uk.
Submitted: December 7, 2017
Accepted: February 7, 2018


Purpose. To demonstrate utility of a game-based test ("Caspar's Castle") for the detection of visual field defects in children.

Methods. A validity and reliability study was carried out at Manchester Royal Eye Hospital Pediatric Ophthalmology Outpatients Department. We recruited 108 children with no eye pathology (aged 4–12 years) and examined a single eye with the Caspar's Castle system using either normal thresholds or thresholds artificially adapted to recreate defects to assess diagnostic utility. Number of peripheral stimuli missed was used to determine sensitivity and specificity of artificial defect detection and to plot receiver-operator characteristic curves. A further 21 children (aged 4–16 years) with pathology were recruited and Caspar's fields compared qualitatively with established field testing. A total of 106 of the Caspar's Castle examinations were able to be performed twice and repeatability was determined through coefficient of repeatability and Bland–Altman chart.

Results. In diagnostic testing using children with no eye pathology, 45 children completed a test using normal thresholds and 43 with tests using artificial defects. Area under receiver-operator characteristic curves for artificial defect detection was 0.895. Of the 21 children with pathology, seven had completed standard Humphreys field testing and Caspar's Castle fields corresponded with each of these by expert opinion. Coefficient of repeatability for number of points missed across all cohorts of children (106 patients) was 6.9 (95% confidence interval: 6.16–8.07).

Conclusions. The Caspar’s Castle system of assessing visual fields using novel game-based strategies demonstrates encouraging levels of sensitivity, specificity, and reliability. It could help address current difficulties in perimetry in young children.

Keywords: perimetry, gamification, glaucoma, neurology

Although more commonly performed in an adult population, perimetry can be of vital importance for the early detection and monitoring of neurological disease and glaucoma in children. Despite challenges associated with inattention and poor compliance,1 Tschopp et al.2 concluded that reliable results can be obtained in children as young as 5 years old once a familiarization procedure has been conducted and if the duration of examination does not exceed the child’s capacity to remain task focused. Morales and Brown3 have demonstrated the feasibility of perimetry using an Octopus automated perimeter in children aged 6 to 12, and normal values for Octopus tendency-oriented perimetry in children 7 through 13 years old have been recorded.4 However, it was noted that when using the Octopus perimeter in younger children aged 6 to 7 years old, significant interindividual variability was present, with testing success dependent on the child’s maturity and ability to concentrate.3 The OPTIC group similarly concluded that good quality perimetry was feasible in children as young as 5 years, but required an experienced examiner with care to ensure balance between performing the test quickly and ensuring children were not overwhelmed.5 They found Goldmann perimetry to be the most effective strategy in children aged 5 to 8 years, but since this perimeter was no longer available, further research was recommended for a suitable alternative.5 More recent findings indicate a simple static perimetry approach potentially yields high-quality results in children younger than 10 years.6 In general, there has been an increasing interest in perimetry in children over the last few years with expert commentary highlighting the importance of continuing to attempt such measurement.7

Our work aims to contribute to this impetus for obtaining easier and higher quality fields in children. We previously presented a game-based visual field test, which demonstrated feasibility in testing children over 4 years of age with a high degree of acceptability.8 It was not dependent on expert, experienced administration and was designed to be as enjoyable as possible. In more recent studies, we developed the physical, psychophysical, and psychological aspects of the test further and obtained normative values for 138 children of different ages.9 This was a key step as although many visual fields are performed in children every year, most tests are...
diagnosed with learning difficulties. Four were excluded from further analyses; three were unable to understand the game (ages 4, 4, and 5 years). Six had lack of concentration to prevent them from completing the game (ages 4 to 12 years), who were either normal, simulated abnormal, or potential pathological fields.

All statistics for diagnostic accuracy and repeatability were performed with MedCalc Statistical Software version 17.6 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2017).

RESULTS

In total, 126 children were recruited to examination with the new Caspar’s Castle game-based supra-threshold field test. Of these, 105 children with no eye pathology were recruited for the objective diagnostics study and 21 children with pathology for potential qualitative comparison of Caspar’s Castle field test with conventional fields.

All children with pathology completed the Castle tests appropriately, but 17/105 children with no eye pathology were excluded from further analyses; three were unable to understand the game (ages 4, 4, and 5 years). Six had lack of concentration to prevent them from completing the game (ages 4, 5, 5, 6, 6, and 9 years). The 9-year-old had previously been diagnosed with learning difficulties. Four were excluded due to poor reliability indices (ages 4, 4, 5, and 6 years). Four
two children with normal conventional fields had normal field loss seen on the Caspar’s Castle game-based test. The ly abnormal conventional tests had corresponding visual field loss seen on the Caspar’s Castle game-based test. The two children with normal conventional fields had normal threshold levels (defect absent) and 43 children did not want to play as they were too tired or scared of the castle (ages 4, 4, 4, and 5 years).

Therefore, data from 88 normal children were used for the diagnostic analysis, involving 45 children completing visual fields with normal threshold levels (defect absent) and 43 children with thresholds that had been manipulated to reflect glaucomatous field defects (defect present). Median age was 6 years (range, 4–10). We determined the total number of points missed in each of these patients’ first Caspar’s Castle fields game and plotted a receiver operator characteristic curve (Fig. 1) using the grouping of defect present or absent as the classification variable. Area under the curve (AUC) was 0.895, which compares favorably with other novel visual field testing, with a combination of fast and standard 24-2 Swedish Interactive Thresholding Algorithm (SITA) threshold strategies (Humphrey visual field [HVF], Carl Zeiss Meditec, Inc., Dublin, CA, USA). For this small sample, we compared the different outputs of the conventional versus game-based field tests qualitatively by ophthalmologists specialized in pediatric glaucoma. Of the seven patients who had achieved conventional SITA field plots, four were pathologically abnormal, two were normal, and one had functional (“clover-leaf” shaped fields) had normal visual fields in the Caspar’s Castle test. Examples of these plots are shown in Figures 2 through 5. Participants from all cohorts were included in the repeatability analyses; 21 with pathology, 45 normal children with normal fields, and 40 normal children with simulated defects. Of the 43 normal children who completed fields with simulated field defects, only 40 completed the game twice due to parents’ desire to leave the clinic quickly.) Thus a total of 106 children were included in the repeatability study. Median age of subjects for the overall repeatability study was 7 years (range, 4–16) and overall average time to complete a game-based field test was 6.5 minutes.

When used as a screening test, it is important to have high levels of specificity to ensure that very few normal subjects are classified as pathological. We were able to recruit 21 children with established pathology where visual field changes might be expected and all children completed the test satisfactorily. Median age was 12 (range, 4–16). Thirteen children had congenital glaucoma, seven had secondary glaucoma, and one had neurological damage to a temporal lobe. Of all patients with pathology, seven had been able to complete conventional field testing, with a combination of fast and standard 24-2 Swedish Interactive Thresholding Algorithm (SITA) threshold strategies (Humphrey visual field [HVF], Carl Zeiss Meditec, Inc., Dublin, CA, USA). For this small sample, we compared the different outputs of the conventional versus game-based field tests qualitatively by ophthalmologists specialized in pediatric glaucoma. Of the seven patients who had achieved conventional SITA field plots, four were pathologically abnormal, two were normal, and one had functional (“clover-leaf” shaped fields). All the pathologically abnormal conventional tests had corresponding visual field loss seen on the Caspar’s Castle game-based test. The two children with normal conventional fields had normal Caspar’s Castle fields. One child who had functional (“clover-leaf” shaped fields) had normal visual fields in the Caspar’s Castle test. Examples of these plots are shown in Figures 2 through 5.

We have been able to demonstrate acceptability and ability to complete visual fields tests in 109/126 children. On diagnostic evaluation with ROC curves, the AUC was found to be 0.895, which compares favorably with other novel visual field screening tools25,26 especially when we consider the challenges we have set ourselves of detecting only mild to moderate defects in young children. The repeatability of the test appears satisfactory with variability of scatter that is consistent across the Bland–Altman chart, around a mean difference of around zero.

Although many challenges have been addressed in development of the current test, improvements to diagnostic performance and repeatability could still be made. Contrary to expectations, many of the instances where the game did not appear to perform well involved older children, aged 9 years or older, some of whom became able to play the central game so adeptly they were perhaps more tempted to scan the periphery as well as responding to central demands. The game was tailored toward younger children, and it may be that...
more complex versions should be developed for older children. However, to achieve optimal clinical impact, test development should remain focused on younger children (e.g., 3–5 years old). Improvements using an eye tracker to monitor fixation should increase sensitivity and specificity, improving clinical utility for all ages. In future developments, we also plan to produce versions that should appeal to girls and boys equally with the main character option to be played by a princess as well as a prince.

Assessment of the system’s diagnostic accuracy was methodologically challenging. Children with known and clinically established defects were relatively rare, even in our large tertiary center. Furthermore, the variety of methods used to represent standard field test outcomes make statistical
comparisons difficult. We therefore chose to demonstrate utility using subjective assessments of children with pathology but also more robust comparisons of children using simulated field defects. However, this use of artificially created field defects might not transfer entirely to real defects in patients and future studies may attempt to compare more rigidly to existing perimetry such as HVFs.

A key feature of the presented Caspar's Castle system is that it is compatible with existing hardware that is already in widespread international use; a computer running Windows 7 service pack 1 or above, suitable screen and trigger device. The surrounding hardboard castle structure was simple to construct and the whole system could be easily available and is inexpensive. Further strengths include independence from...
Diagnostic Performance of a Game-Based Field Test

expert supervision requirement as well as ease of use and attractiveness to children. These features suggest potential utility particularly as a screening tool outside of specialized hospital settings. Examples of children aged 5 and 7 playing the test can be seen in Supplementary Videos S1 and S2, respectively.

In summary, Caspar’s Castle represents a novel, affordable, noninvasive and entertaining means of obtaining visual field results from younger children with acceptable validity and reliability. It could be a useful tool in clinical practice to assist with the challenges of pediatric perimetry.

Acknowledgments

This paper presents independent research funded by the National Institute for Health Research (NIHR) under its Research for Patient Benefit (RfPB) Programme (Grant Reference Number PB-PG-0211-24064) and by an Independent Glaucoma Association Grant, IGA/ UKEGS2015 (YW). The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR, or the Department of Health.

Disclosure: T.M. Aslam, Novartis (C, R), Bayer (C, R), Thea Pharmaceuticals (C, R) Bausch & Lomb (C, R), Oraya (C, R); None; Y. Wang, None; C. Fenerty, None; S. Biswas, None; E. Tsamis, None; D.B. Henson, None

References