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## **A novel paediatric game-based visual fields assessor**

Tariq M Aslam<sup>1,2</sup>, FRCSEd (Ophth), DM (OXON)  
Waheeda Rahman<sup>1</sup>, FRCOphth  
David Henson<sup>2</sup>, PhD, FBCO  
Peng T Khaw<sup>1</sup>, PhD, FRCOphth.

1. NIHR Biomedical Research Centre Moorfields Eye Hospital and UCL Institute of Ophthalmology
2. NIHR Biomedical Research Centre Manchester Royal Eye Hospital and University of Manchester

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Competing Interest: None declared.

**Running Head :** Game-based perimetry

**Address for reprints :** Mr Tariq M Aslam, Manchester Royal Eye Hospital, Oxford Road, Manchester, U.K. M13 9WL

Measurement of visual fields can be prohibitively difficult in children, particularly below the age of 10-11 years.<sup>1,2</sup> Problems include lack of central fixation,<sup>3</sup> short attention span<sup>3,5</sup> and intolerance. Recent systems have demonstrated user interaction<sup>2,6</sup> may improve tolerance and reliability in children and have demonstrated the potential for personal computer testing.<sup>7</sup> Other recent innovations include eye tracking technology, proposed in 1989<sup>8</sup> and developed at the University of Tokyo.<sup>9</sup> However, this requires expensive apparatus and has not yet been validated.<sup>10</sup>

Our aim was to determine whether a computer game system could be devised to measure visual fields in children whilst they play and enjoy an entertaining game.

### **Methods**

The study had full ethics Committee approval and informed consent was obtained from all participants and parents. The development of the game-based visual fields assessor relied on multi-disciplinary input and combined international perimetric society standards<sup>11</sup> with computer game science. The final system uses a supra-threshold examination strategy with fixed intensity. Background luminance and other psychophysical constants were set for this feasibility study based on literature review and estimations from adult trials of the test.

The software was developed using BBC basic /windows v5.80a and was conceived and written by the first author. Game design acknowledged Bateman and Boon's <sup>12</sup> game play types and Salen and Zimmerman <sup>13</sup> and Mulligan & Patrovsky <sup>14</sup> theories on player psychologies. We adopted the iterative game design process advocated by Salen and Zimmerman <sup>13</sup> and Fullerton et al., <sup>15</sup> which relies on gaining feedback from players early on and repeated game redesign - our game resulted from 17 cycles of appraisal and reprogramming. Development included designing instructions for explaining how to play the 'Crazy Castle' game and a cohesive storyline that ties in all that is required of the player.

The complete game structure consists of a large wooden castle (1m<sup>3</sup>) with a set of occludable spectacle frames attached to a large central window on an exterior castle wall (fig. 1). A closed wooden drawbridge barrier obstructs view through the window into the castle. When a child's forehead is correctly aligned in the glasses (fig. 2,3) a switch activates opening of the drawbridge which then reveals a computer game on a screen (fig.3) inside the castle, at a set distance from the spectacle frames. If the correct alignment is lost, the drawbridge instantly closes, hiding the game screen from view

The child uses an attached keypad to play the game, which is separated into four stages, allowing for the child to learn to play whilst maintaining position and for the software to set individualised variables. The game premise involves a small central character of a wizard with a plunger. When a tomato hovers under this plunger, the child presses the appropriately textured console button to squash the tomato (central fixation game). This central game is moved to different corners of the screen and peripheral field targets appear intermittently as ghosts in remaining corners. The child must continue the central fixation game but is encouraged to press a separate button when he sees these peripheral ghosts (peripheral target game). These ghosts (fig 4) appear at 10, 20 and 30 degrees from the central fixation game at each of 4 axes (see fig. 4 and 5). They are presented for 200 milliseconds and increase in size if no response is provoked. Each tested peripheral target is graded 0 (not seen), 1 (5mm size seen), 2 (4mm), 3 (3mm) or 4 (2mm). <sup>16</sup> Missed stimuli are responded to with repeat testing. In accordance with perimetric standards and computer game theory, there are multiple programming measures, animations, sound effects and graphics incorporated to optimise central fixation importance, reduce false negatives and false positives and optimise utility of the game. The examiner is able to monitor progress on a separate laptop adjacent to the castle. Once tested, the children were invited to respond to a questionnaire about their experience with the visual field exam.

## Results

19 children were recruited from an outpatient department at the Richard Desmond Children's Eye Centre at Moorfields Eye Hospital. Tests were carried out in the Fight for Sight NIHR Children's Research Facility. 2 children failed to complete the exam due to hardware and software failures that were subsequently corrected.

23 fields were completed, in 23 eyes of 17 children (6 bilateral). All completed fields had physiological blind spots found. Normal fields were defined through earlier pilot studies on normal adults. Median time for completion of the tests including training stages was 4.5 minutes (range 3.11 -8.0 minutes). There were 8 girls and 9 boys, aged 4 - 14yrs (5 children aged 4-6, 8 aged 7-10 and 4 aged 10-14).

Two four year olds with expected normal fields showed general delay in response which, according to our preset definitions, was classed as abnormal. The problems for these two children included, firstly, requiring a greater time to learn the game than was currently programmed into the system. Furthermore the requirement of two separate buttons to respond in the course of the game was perhaps too complex and a single button option might be more

apt in this age group. However, it was very promising that they both still fully completed the tests, and we feel that reducing game difficulty for this age would counter the problems that arose.

For all 15 other eyes with clinically expected normal fields (all normal eyes of children aged over 4), the children were, at their first attempt, able to complete the assessment giving normal visual fields. This included 3 children aged 6 and under. For the 5 eyes with expected glaucomatous loss, all 5 visual fields measured showed abnormal fields. Discrimination potential and acceptability of test are demonstrated in Fig. 4 and Fig. 5. In questionnaires, all children enjoyed playing the game and gave positive feedback.

## Discussion

The gaming system has shown great promise, in this feasibility study, to provide clinically useful information in a way that is accessible and enjoyable for the child with no discomfort or potential for harm. Developments need to be made in terms of shortfalls in hardware and software as well as in optimising the psychophysical consistency and validity of peripheral targets. Ultimately we anticipate this system being particularly useful for perimetry in targeted groups of children in terms of age, aptitude, personality and physical ability. Formal validation and further reliability studies will be required before the system can be presented as a fully validated and reliable clinical tool. The final technology would potentially have a greater diagnostic precision and sensitivity to identify visual fields loss than existing tests. The test would be quicker and more reliable and therefore be a lesser drain on resources. It would be more affordable than alternative proposals in development and more enjoyable to experience for the child than any current system. It has potential for worldwide adoption due to its basis upon widely available and affordable technology. In modified form, the game-based system could also be utilised for other visual function measurements such as acuity and contrast sensitivity.

**Fig. 1 Paediatric game-based vision assessor**

**Fig. 2 Child waiting to play game, holding control pad then correctly positioned to see and play game**

**Fig. 3 Examples of images seen in game;** a) Tomato correctly positioned to mash, b) Tomato being mashed, c) peripheral ghost being lasered

**Fig. 4 Discrimination potential.** Fields measured of 14 yr old boy with no ocular pathology in RE, but with glaucoma and suspected field defects found in his LE that corresponded with those found on Humphrey testing. Note in RE almost all targets were seen normally (score 3 or 4). In LE there are several areas of lost field (7 out of the 24 tested areas score less than 3). LE field was done after the RE

**Fig. 5 Acceptability of test.** This 11 yr old child had documented poor compliance with standard fields tests and none were found acceptable. Goldman fields were not successful and Humphreys fields showed multiple areas of field loss with poor fixation. On his first attempt with our game-based fields analyser, however, he returned good peripheral fields whilst demonstrating good central target fixation, in accordance with his clinically expected visual function.

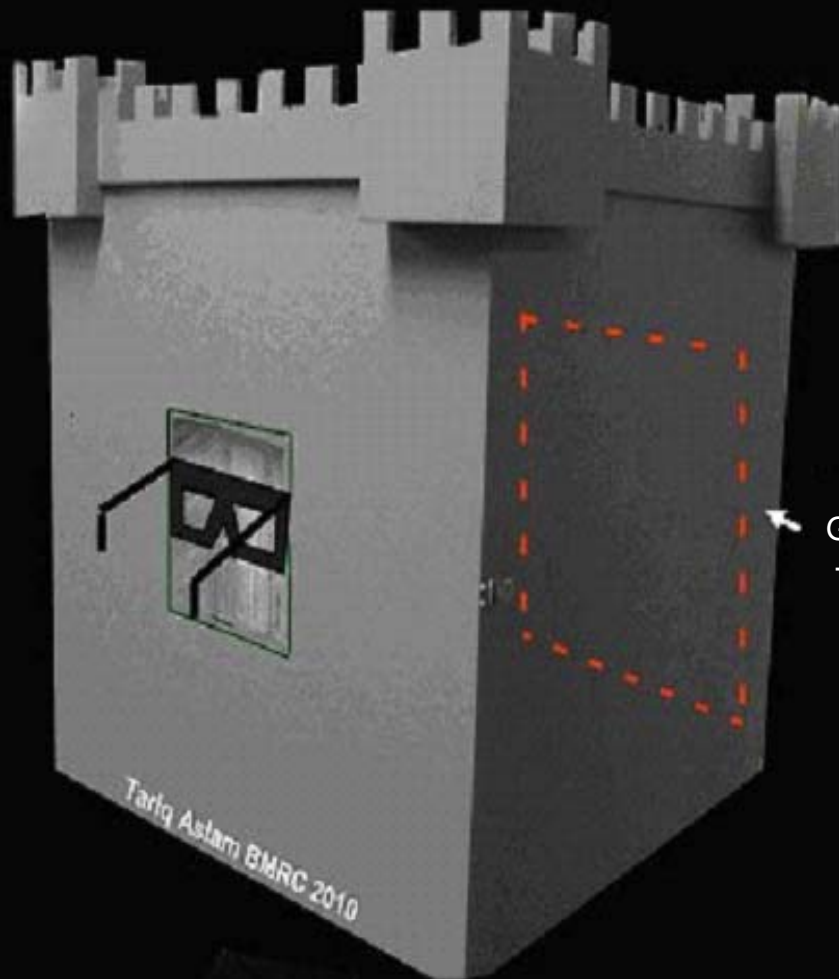
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Game screen  
-visible inside  
castle



Control pad

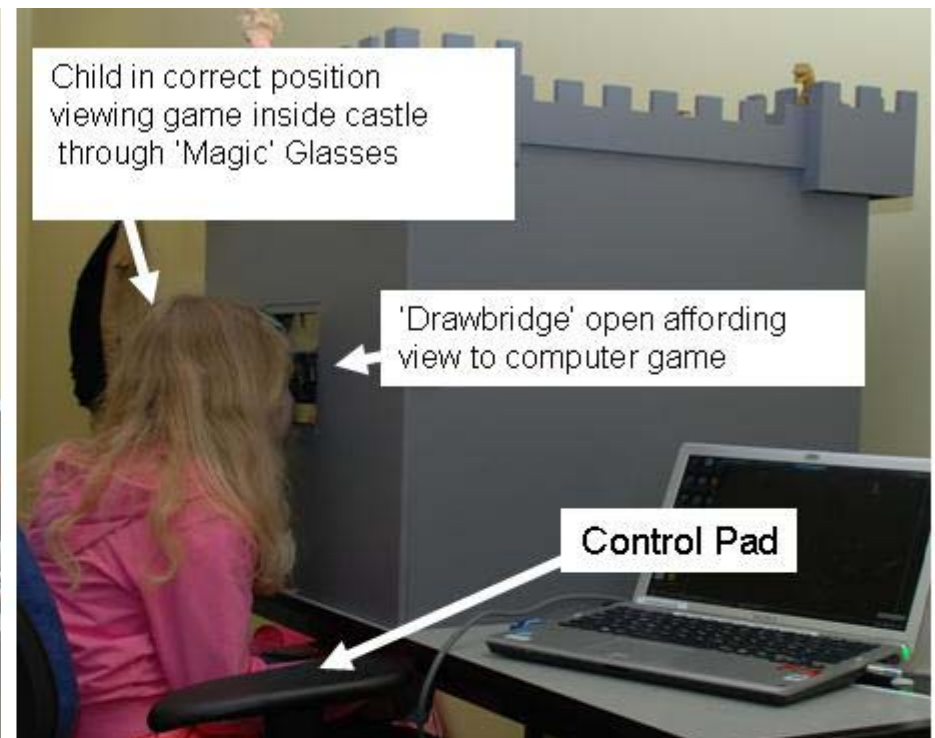
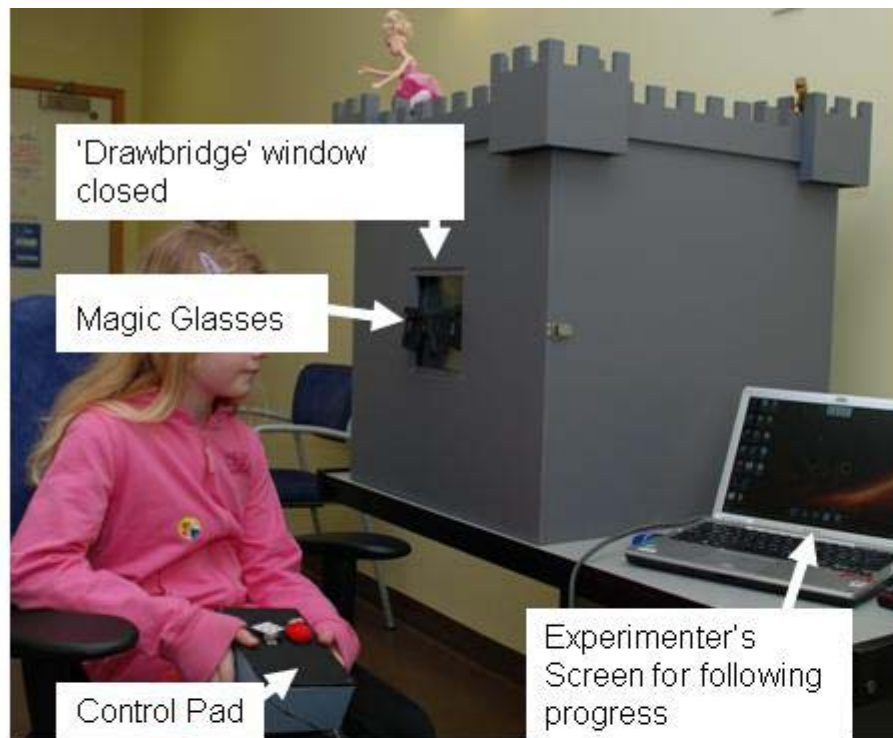






fig 3(a)

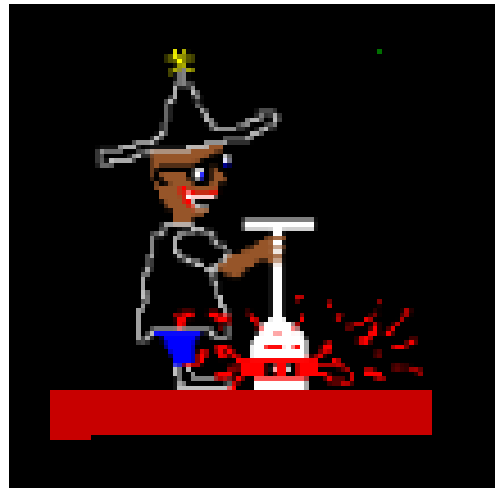


fig 3(b)

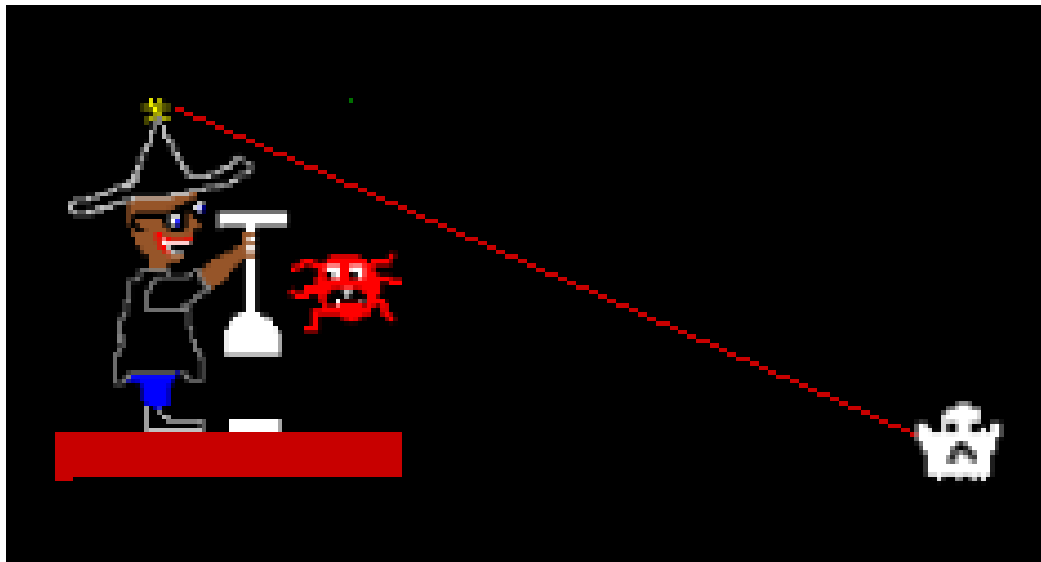


fig 3(c)

3			4			2
	3		3		3	
		3	1	3		
3	2	0 3	x	4	2	4
		3	3	3		
	4		2		3	
3			1			1

Left eye ( glaucoma)

3			2			4
	4		4		4	
		4	4	3		
4	3	3	x	4 0	4	4
		3	3	3		
	4		4		4	
3			3			4

Right eye ( normal)

4			4			4
	3		4		4	
		4	4	4		
4	4	4	X	04	4	4
		4	4	4		
	4		3		4	
2			4			4