Searching for unity: Real-world versus item-based visual search in age-related eye disease

David P. Crabb and Deanna J. Taylor

Division of Optometry and Visual Science, School of Health Sciences, City, University of London, London EC1V 0HB, United Kingdom.

david.crabb.1@city.ac.uk

http://www.staff.city.ac.uk/crabblab

deanna.taylor@city.ac.uk

http://www.staff.city.ac.uk/crabblab

Abstract: When studying visual search, item-based approaches using synthetic targets and distractors limit the real-world applicability of results. Everyday visual search can be impaired in patients with common eye diseases like glaucoma and age-related macular degeneration. We highlight some results in the literature that suggest assessment of real-word search tasks in these patients could be clinically useful.

Visual search is an important everyday visual function. Many laboratory studies of visual search use synthetic targets and distractors. Such experiments are somewhat removed from the holistic approach needed to find a face in a crowd, search for an exit sign at an airport or locate a favourite cereal on the supermarket shelf. So we agree with Hulleman & Olivers' (H&O's) contention that "item-based approaches limit the real-world applicability of results from the lab" (sect. 4.1, para. 1). H&O discuss two real-world applications of visual search: radiology and airport security. In this commentary we highlight search as an impaired everyday visual function in people with age-related eye disease. We speculate on how this might be best assessed with the idea of bringing visual search out of the lab and into clinical research, focussing on open angle glaucoma and age-related macular degeneration (AMD), two of the most common causes of visual impairment worldwide (Lamoureux et al. 2008). Glaucoma is typically associated with peripheral vision loss, whilst AMD causes loss of central vision.

Most studies of visual search in age-related eye disease used an item-based approach (for example, Jacko et al. 2000; , 2001), yet examples taking a more real-world approach are emerging. We investigated visual search in people with glaucoma using two computer-based tasks (Smith et al. 2011), one item-based task requiring participants to identify a target from an array of distractors, and another more real-world task requiring participants to find everyday items in digital photographs of indoor and outdoor scenes. Participants with glaucoma exhibited longer average search times than healthy peers for the real-world task, whilst search times were not significantly different between the two groups for the item-based task. These results support the notion that item-based search tasks are not relatable to real-world applications. A further study (Smith et al. 2012), investigating eye movements during the same real-world visual search task, reported a reduction in saccade frequency in people with glaucoma compared with healthy peers. Furthermore, amongst participants with glaucoma, those who made more saccades per second were quicker in finding the real-world targets. These results indicate that eye-movement behaviour is of importance when considering visual search performance of people with age-related eye disease, and were supported by a study of similar design when detecting faces (Glen et al. 2013). These findings align with H&O's proposition that fixation count is a critical factor in visual search behaviour.

Fixation count has been investigated in real-world search tasks in AMD. Most visual search research in AMD has been conducted using artificial arrays (for example, searching for a letter T amongst distractors in the form of the letter L) and participants with simulated scotomas (for example Bertera 1988; Coeckelbergh et al. 2002; Cornelissen et al. 2005; Geringswald et al. 2012; 2013; Kuyk et al. 2005; MacKeben & Fletcher 2011; Murphy & Foley-Fisher 1988; 1989). These approaches allow for more controlled experimental design, yet simulated scotomas may not be entirely realistic (Harvey & Walker 2014; Schuchard et al. 1999). One method of simulating central scotoma uses contact lenses with a central opacity, which cause reduced retinal illumination, leading to worsening in visual acuity and contrast sensitivity (Butt et al. 2015). A gaze-contingent simulation of scotoma, incorporating eye tracking, is likely to provide better scotoma simulation (Butt et al. 2015); we have used this in a hazard search task in driving (Glen et al. 2015). Results were useful, but simulation cannot capture the real experience of patients, where self-reported perception and description of scotoma varies enormously (Crabb et al. 2013). A few studies have investigated real-world visual search in actual patients with AMD; for example Thibaut et al. (2015) reported individuals with AMD exhibit higher saccade frequencies, shorter fixation durations and longer scan paths compared with those without AMD during visual search. Aspinall et al. (2014) found fixation count to be a useful marker of situations subjectively classed as “difficult” by individuals with AMD when assessing eye movement behaviour whilst watching videos of ambulatory journeys. Similarly, Geruschat et al. (2006) investigated gaze behaviour during street crossing and reported higher fixation count during more difficult/visually demanding parts of the task. Seiple et al. (2013) observed people with AMD whilst exploring faces and reported fixation count for internal facial features (eyes, nose, and mouth) to be higher for controls than for individuals with AMD. All of these tasks transcend the traditional item-based search.

Studies of everyday visual search have real clinical implications. Visual search in people with visual impairment has been suggested as a predictor for mobility and performance of other daily activities (Kuyk et al. 2005). There is evidence for the effectiveness of eye movement training on visual search in congenital prosopagnosia (Schmalzl et al. 2008), following brain damage (Bouwmeester et al. 2007), and for improved visual search and mobility performance in people with visual impairment of ocular origins following repeated practice of an item-based search task (Kuyk et al. 2010; Liu et al. 2007). These types of findings could lead to interventions and alternative approaches to management of patients. Potential also exists for development of tests for detecting and monitoring eye disease by using visual search in both item-based (Loughman et al. 2007) and real-world (Crabb et al. 2014) scenarios.

An article published nearly 30 years ago about tumour detection using visual search (Nodine & Kundel 1987) states that “detecting an object that is hidden in a natural scene is not the same as detecting an object displayed against a background of random noise." Research in this area ought to bridge the gap between lab-based testing and the real-world. H&O have made an important step towards unifying some of the theory of visual search. We anticipate this will stimulate practical studies that may lead to better understanding of visual search in people with age-related eye disease. In turn we speculate that this will have implications for rehabilitation, and potentially lead to development of new tests for monitoring age-related eye disease.

References

Aspinall, P. A., Borooah, S., Al Alouch, C., Roe, J., Laude, A., Gupta, R., Gupta, M., Montarzino, A. & Dhillon, B. (2014) Gaze and pupil changes during navigation in age-related macular degeneration. *British Journal of Ophthalmology* 98:1393–97.

Bertera, J. H. (1988) The effect of simulated scotomas on visual search in normal subjects. *Investigative Ophthalmology and Visual Science* 29(3):470–75.

Bouwmeester, L., Heutink, J. & Lucas, C. (2007) The effect of visual training for patients with visual field defects due to brain damage: A systematic review. *Journal of Neurology, Neurosurgery & Psychiatry* 78(6):555–64.

Butt, T., Crossland, M. D., West, P., Orr, S. W. & Rubin, G. S. (2015) Simulation contact lenses for AMD health state utility values in NICE appraisals: A different reality. *British Journal of Ophthalmology* 99(4):540–44.

Coeckelbergh, T. R. M., Cornelissen, F. W., Brouwer, W. H. & Kooijman, A. C. (2002) The effect of visual field defects on eye movements and practical fitness to drive. *Vision Research* 42(5):669–77.

Cornelissen, F. W., Bruin, K. J. & Kooijman, A. C. (2005) The influence of artificial scotomas on eye movements during visual search. *Optometry and Vision Science* 82(1):27–35.

Crabb, D. P., Smith, N. D., Glen, F. C., Burton, R. & Garway-Heath, D. F. (2013) How does glaucoma look?: Patient perception of visual field loss. *Ophthalmology* 120(6):1120–126.

Crabb, D. P., Smith, N. D. & Zhu, H. (2014) What's on TV? Detecting age-related neurodegenerative eye disease using eye movement scanpaths. *Frontiers in Aging Neuroscience* 6:312.

Geringswald, F., Baumgartner, F. & Pollman, S. (2012) Simulated loss of foveal vision eliminates visual search advantage in repeated displays. *Frontiers in Human Neuroscience* 11(6):134.

Geringswald, F., Herbik, A., Hoffman, M. B. & Pollman, S. (2013) Contextual cueing impairment in patients with age-related macular degeneration. *Journal of Vision* 13(3):28.

Geruschat, D. R., Hassan, S. E., Turano, K. A., Quigley, H. A. & Congdon, N. G. (2006) Gaze behaviour of the visually impaired during street crossing. *Optometry and Vision Science* 83(8):550–58.

Glen, F. C., Smith, N. D. & Crabb, D. P. (2013) Saccadic eye movements and face recognition performance in patients with central glaucomatous visual field defects. *Vision Research* 82:42–51.

Glen, F. C., Smith, N. D. & Crabb, D. P. (2015) Impact of superior and inferior visual field loss on hazard detection in a computer-based driving test. *British Journal of Ophthalmology* 99(5):613–17.

Harvey, H. & Walker, R. (2014) Reading with peripheral vision: A comparison of reading dynamic scrolling and static text with a simulated central scotoma. *Vision Research* 2014 98:54–60.

Hulleman, J. & Olivers, C. N. L. (2015) The impending demise of the item in visual search. *Behavioural and Brain Sciences* 17:1–76.

Jacko, J. A., Barreto, A. B., Chu, J. Y. M., Scott, I. U., Rosa Jr, R. H. & Pappas Jr, C. C. (2000) Macular degeneration and visual search: What we can learn from eye movement analysis. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 44(29):116–19.

Jacko, J. A., Scott, I. U., Barreto, A. B. Bautsch, H. S., Chu, J. Y. M. & Fain, W. B. (2001) Iconic visual search strategies: A comparison of computer users with AMD versus computer users with normal vision. *Proceedings of the Ninth International Conference on Human-Computer Interaction* 2:423

Kuyk, T. K., Liu, L. & Fuhr, P. S. W. (2005) Feature search in persons with severe visual impairment. *Vision Research* 45(25–26):3224–34.

Kuyk, T. K., Liu, L., Elliott, J. & Fuhr, P. S. W. (2010) Visual search training and obstacle avoidance in adults with visual impairments. *Journal of Visual Impairment & Blindness* 104(4):215–27.

Lamoureux, E. L., Pallant, J. F., Pesudovs, K., Tennant, A., Rees, G., O'Connor, P. M. & Keefe, J. E. (2008) Assessing participation in daily living and the effectiveness of rehabilitation in age related macular degeneration patients using the impact of vision impairment scale. *Ophthalmic Epidemiology* 15(2):105–13.

Liu, L., Kuyk, T. K. & Fuhr, P. S. W. (2007) Visual search training in subjects with severe to profound low vision. *Vision Research* 47(20):2627:2636.

Loughman, J., Davison, P. & Flitcroft, I. (2007) Open angle glaucoma effects on preattentive visual search efficiency for flicker, motion displacement and orientation pop-out tasks. *British Journal of Ophthalmology* 91(11):1493–98.

MacKeben, M. & Fletcher, D. C. (2011) Target search and identification performance in low vision patients. *Investigative Ophthalmology and Visual Science* 52:7603–609.

Murphy, K. St. J. & Foley-Fisher, J. A. (1988) Visual search with non-foveal vision. *Ophthalmic and Physiological Optics* 8(3):345–48.

Murphy, K. St. J. & Foley-Fisher, J. A. (1989) Effect of a scotoma on eye movements during visual search. *Ophthalmic and Physiological Optics* 9(3):317–21.

Nodine, C. F. & Kundel, H. L. (1987) Using eye movements to study visual search and to improve tumor detection. *Radiographics* 7(6):1241–50.

Seiple, W., Rosen, R. B. & Garcia, P. M. T. (2013) Abnormal fixation in individuals with age-related macular degeneration when viewing an image of a face. *Optometry and Vision Science* 90(1):45–56.

Schmalzl, L. Palermo, R., Green, M., Brunsdon, R. & Coltheart, M. (2008) Training of familiar face recognition and visual scan paths for faces in a child with congenital prosopagnosia. *Cognitive Neuropsychology* 25(5):704–29.

Schuchard, R. A., Naseer, S. & de Castro, K. (1999) Characteristics of AMD patients receiving visual rehabilitation. *Journal of Rehabilitation Research and Development* 36(4):294–302.

Smith, N. D., Crabb, D. P. & Garway-Heath, D. F. (2011) An exploratory study of visual search performance in glaucoma. *Ophthalmic and Physiological Optics* 31(3):225–32.

Smith, N. D., Glen, F. C. & Crabb, D. P. (2012) Eye movements during visual search in patients with glaucoma. *BMC Ophthalmology* 12:45.

Thibaut, M., Delerue, C., Boucart, M. & Tran, T. H. C. (2015) Visual exploration of objects and scenes in patients with age-related macular degeneration. *Journal français d'ophtalmologie* 39:82–89.