Project Proposal for eNTERFACE'13

A novel tool to improve vision in adults with amblyopia

Themes: Medical and health applications, assistive and rehabilitation technologies, game and serious game applications, multimodality for plasticity.

Principal investigator: Dr. Andrew Astle

Candidates:

2 Computer Scientists or Software Developers with game design experience

Graphic Designer with game design experience

Graphic User Interface Designer

Abstract:

Amblyopia, also known as "lazy eye", is the leading cause of vision loss in children. In the vast majority of cases, the condition persists into adulthood. However, there is currently no available treatment for adults with the condition. Recent work has demonstrated improvements in adults with amblyopia following repeated practice of certain basic visual tasks and has identified the optimum tasks to train on. This project will create a video game based on robust scientific research that incorporates these key tasks into an entertaining and engaging video game to maximise improvements. The game will provide amblyopic adults with a tool to improve vision in their own homes. Improved vision in amblyopes is associated with better employment prospects, a higher quality of life and a lower risk of blindness.

Project objectives

Research on basic perceptual mechanisms has shown that repeatedly practicing certain visual tasks improves vision in normally sighted adults, and in adults with amblyopia. These practice-induced improvements in perception are referred to as perceptual learning, and are evidence that the plasticity of the adult visual system can be harnessed for rehabilitative purposes (see[1] for a review).

Concurrently, recent studies suggest that playing off-the-shelf video games can improve vision in adults with amblyopia[2]. However, these games do not incorporate the precise visual demands that produce the maximum improvement in vision. I propose the production of a video game that incorporates the key ingredients that I have identified in my research, to enhance visual function in adults with amblyopia[3].

Background information

Amblyopia is a common developmental visual disorder, affecting 2-6% of the population. People with amblyopia have reduced vision in one eye, which is not improved by wearing glasses or contact lenses, and often have poor depth perception. Ambylopia is the leading cause of monocular vision loss in children, and accounts for most children's eye appointments in the U.K. Amblyopia persists into adulthood in the vast majority of cases (80%)[4]. For adults between the ages of 49 and 69 years of age, it is the major cause of both mild, and moderate to severe visual impairment. It precludes people from many occupations[5], leads to a lower quality of life[6] and increases the risk of future sight loss[7]. Traditionally, amblyopia has only been treated in children, since it was thought that the adult visual system was incapable of improvement. Traditional treatment involves patching the good eye for extended periods of time during childhood. Compliance to patching treatment is poor and has numerous disadvantages. There is currently no treatment for adults with amblyopia. However, there is now mounting evidence to show that vision can be improved in adults with the condition.

Perceptual learning refers to the improvements in perceptual performance obtained after repeated practice. Perceptual learning has been demonstrated on a variety of tasks from wine tasting to recognising abnormalities on X-rays. Recent perceptual learning studies have shown that the adult amblyopic visual system possesses significant neural plasticity and is capable of improvement[1]. My work has identified the key ingredients that lead to the greatest improvements[3].

These ingredients are: (i) detecting low contrast (faint) objects, (ii) detecting small objects, (iii) aligning objects, and (iv) detecting targets surrounded by other objects (i.e. "crowded objects"). In addition, actively engaging attention and providing reward through game play further enhances the efficacy of training. Improvements in vision in an amblyopic eye are likely to precede improvements in depth perception, reduce the likelihood of accidents and improve employment prospects.

Detailed technical description

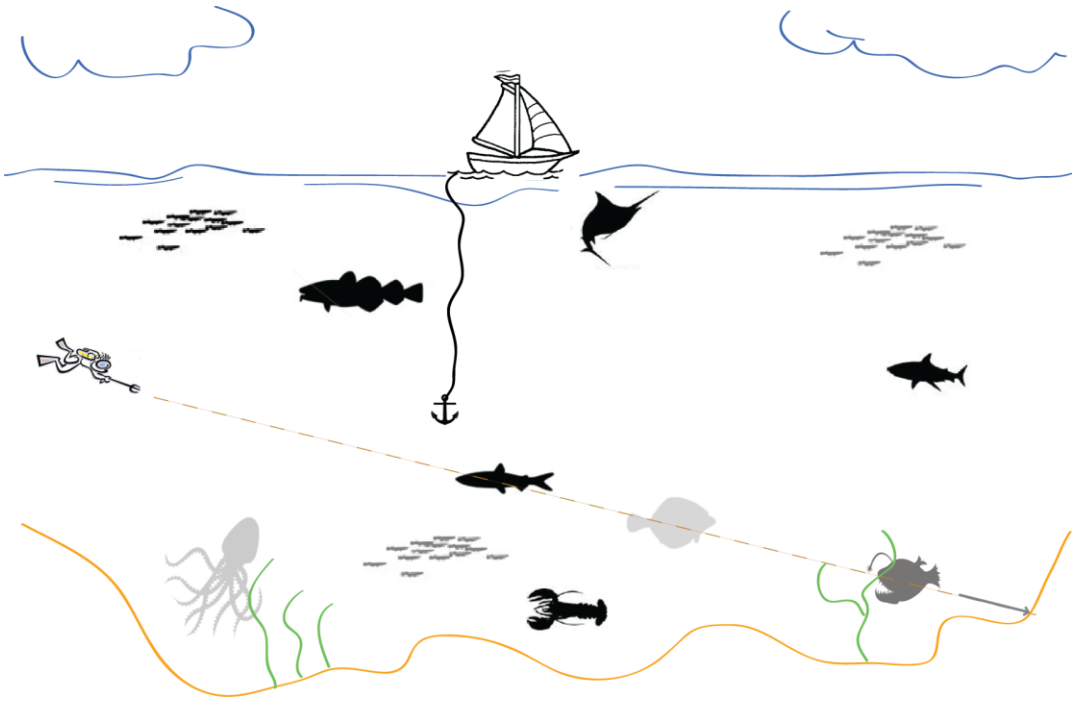
Technical description

It is important that the game incorporates the key ingredients highlighted above. The game will be engaging, entertaining and challenging. It will hold the player's attention and keep them motivated. These are characteristics of all successful video games. Furthermore, the game will capitalise on visual challenges known to tap into adult visual plasticity. This will drive improvements in visual performance and maximise the efficiency of the approach.

There are numerous game concepts into which the key ingredients can be built and some of the time on the project will involve discussion between all parties to decide on a final design. One of the benefits of eNTERFACE is the potential for combining knowledge from different fields through collaboration. Computer scientists/software developers and a graphic designer with experience in game design will be able to contribute vital input into the final design. This will ensure that the game is entertaining and enjoyable – making it something people *want* to play. This is important to the success of this approach. Purely as an example, below I describe a game that includes each of the ingredients.

Potential game concept:

The game involves control of a diver with a harpoon (please see diagram below for basic concept). The aim is to get the diver to catch fish with their harpoon by aiming at the fish and firing. The diver must also avoid certain predatory fish like sharks. The diver starts at a shallow depth, where water visibility (and the contrast of objects) is generally good - fish are seen relatively easily. Points are required to progress to the next level and are achieved by catching fish. Certain fish should be caught – which makes it necessary for players to detect the different shapes of fish. Fish may be relatively easy or difficult to detect and locate depending on their size, contrast, speed of movement and proximity of surrounding fish. Catching multiple fish, by lining them up with the trajectory of the harpoon, results in bonus points being awarded. Certain endangered fish need to be avoided. Different levels and achievements are included to increase motivation of players. Once a certain quota of particular fish has been caught, the player progresses to the next level. This needs to be achieved in a particular period of time (before the diver's oxygen runs out). The next level would involve the diver going to a greater depth. The task of catching fish in subsequent levels is made more difficult due to reduced visibility at greater depths, which reduces the contrast of the fish. Fish can also be made smaller and faster and the amount of bubbles, floating debris and small marine animals can be increased to make it even more difficult.



Calibration/display: Accurate visual display of the game elements is important. Therefore, a calibration process will be built into the game. This will calibrate the spatial, luminance and chromatic characteristics of each display. The game will need to be able to display objects over a large range of contrast levels. Established methods in vision science for increasing the dynamic range of contrasts that can be displayed on computer screens (e.g. bit swapping) will be implemented into the game.

Viewing distance, head tracking: In order to accurately control the effective size of the game elements, a fixed and constant distance between the display and player is required. To ensure this, a distance-monitoring feature will be developed that uses a camera (e.g. webcam or front-facing camera of tablet device) to measure the distance between the player's eyes and track their distance from the screen.

Adaptive method: The game will adapt according to the performance of the player (getting more difficult when players do better). This adaptive (e.g. staircase) procedure is used commonly in vision science to modulate the difficulty level. The method is beneficial since the level of difficulty has been shown to be important in determining the extent of improvements. Improvements are greatest when people practice close to their threshold

level for the task. Additionally, amblyopia is a very variable condition and what is easy to see for some amblyopes will be difficult to see for others. Therefore, tracking performance will allow the difficulty level to be tailored to each person's specific deficits and to their changing performance throughout the training period. To encourage players and maintain motivation, some easier challenges will be interspersed with the more difficult training trials. I will develop the psychophysical strategy for the game.

Data tracking/management: The performance of each individual will be tracked and displayed to them. This will allow them to monitor their progress and will increase motivation. The information will be stored and will allow assessment of the success of the game at improving vision and inform future research.

Resources needed: facility, equipment, software, staff...

A computer for the computer scientists, GUI designer and graphic designer will be required for game development and graphic design. Additionally, access to an iPad (with front facing camera) or webcam will enable the implementation of a distance checking feature into the game. Development software for each of the developers will be required. Developers may have personal preferences on software and many tools are now freely available (e.g. iOS Developer Program). Creative software will be required by the graphic designer (e.g. Adobe Creative Suite). Additionally many sound effects, graphics and game engines are now available free of charge online (e.g. Blender game engine). These libraries will be valuable in allowing sufficient time to be spent developing the game given the timeframe of the project. Involvement of a graphic designer and software developers with experience of game design will ensure that time is spent effectively designing and developing the game rather than on familiarisation with software.

Project management:

All members will have individual tasks and goals according to their respective roles. Regular meetings will be held to keep the team informed of progress and ensure successful completion of objectives identified at the start of the project.

Work plan and implementation schedule

Objective 1: Finalisation of game concept and design will take place at the start of the first week.

Objective 2: The remainder of the first week, and the second and third weeks will be used to build the game. This will include the combination of the graphics and sound elements along with the game engine (some of which are readily available from online libraries).

Objective 3: Development of a system to measure the distance of the player from the display and a system to log the performance of those undergoing training with the game. This will be completed during the second and third weeks.

Objective 4: The final week will involve evaluation of the game and resolution of any identified problems. It will include uploading the game to the internet so that it is freely and widely available. At the end of week four, the game will be demonstrated and a presentation given to report on the success of the project.

Benefits of the research

There is currently no treatment available for adults with amblyopia. The project will result in the production of a freely available, novel game based on robust scientific research, which will allow people with amblyopia to improve their vision in their own homes.

Improved vision will increase employment prospects [5] and quality of life [6] in people with the condition. Additionally, it will reduce the devastating impact of loss of vision in the good eye (e.g. through trauma or pathology) and reduce the risk of future blindness [7]. By increasing vision in the weaker eye, the game will increase the chance of adult amblyopes achieving good depth perception.

Home-based rehabilitation has previously been used successfully in different patient populations including people with hearing problems and stroke patients. The benefits of home-based rehabilitation include reduced costs and increased compliance.

Performance data for each game from each individual will be collected and stored centrally. These data will enable further refinement and inform future research on amblyopia and home-based rehabilitation strategies. The project will result in a follow-up clinical trial that will assess the efficacy of the game at improving vision in adult amblyopes.

Profile of the team

Leader: Andrew Astle

A post doctoral researcher with experience in eye-care and vision research. Experienced in calibrating visual displays, programming visual training experiments and collecting behavioural data. Current research topics include spatial vision and visual rehabilitation. PhD research focussed on improvements in adults with amblyopia and identified the types of tasks which lead to the greatest improvements in vision. This work has been published in scientific journals and provides proof of principle of the approach to be taken by the proposed eNTERFACE project.

Other researchers

1) Computer Scientist or Software Developer with experience in game design.
2) Computer Scientist or Software Developer with experience in game design.
3) Graphic Designer with game design experience.
4) Graphic User Interface Designer.

References

1. Levi, D. M. Prentice award lecture 2011: Removing the brakes on plasticity in the amblyopic brain. *Optom. Vis. Sci.* **89**, 827-838 810.1097/OPX.1090b1013e318257a318187 (2012).
2. Li, R. W., Ngo, C., Nguyen, J. & Levi, D. M. Video-game play induces plasticity in the visual system of adults with amblyopia. *PLoS Biol*. **9** (2011).
3. Astle, A. T., Webb, B. S. & McGraw, P. V. The pattern of learned visual improvements in adult amblyopia. *Invest Ophthalmol Vis Sci*. **52**, 7195-7204 (2011).
4. Rahi, J. S., Cumberland, P. M. & Peckham, C. S. Does amblyopia affect educational, health, and social outcomes? Findings from 1958 british birth cohort. *BMJ*. **332**, 820-825 (2006).
5. Adams, G. G. & Karas, M. P. Effect of amblyopia on employment prospects. *Br. J. Ophthalmol.* **83**, 380 (1999).
6. Membreno, J. H., Brown, M. M., Brown, G. C., Sharma, S. & Beauchamp, G. R. A cost-utility analysis of therapy for amblyopia. *Ophthalmology*. **109**, 2265-2271 (2002).
7. Rahi, J., Logan, S., Timms, C., Russell-Eggitt, I. & Taylor, D. Risk, causes, and outcomes of visual impairment after loss of vision in the non-amblyopic eye: A population-based study. *Lancet*. **360**, 597-602 (2002).