Assisting autistic children with wireless EOG technology

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Summary

We propose a novel intervention [1] to train the speed and accuracy of attention orienting and eye movements in Autism Spectrum Disorder (ASD). Training eye movements and attention could not only affect those important functions directly, but could also result in broader improvement of social communication skills. To this end we describe a system that would allow ASD children to improve their fixation skills while playing a computer game [2] controlled by an eye tracker. Because this intervention will probably be time consuming, this system should be designed to be used at homes. To make this possible, we propose an implementation based on wireless and dry electrooculography (EOG) technology. If successful, this system would develop an approach to therapy that would improve clinical and behavioral function in children and adults with ASD. As our initial steps in this direction, here we describe the design of a computer game to be used in this system, and the predictions of gaze position from EOG data recorded while a subject played this game.

Methods

Experimental setup: Figure 1 shows the setup for the experiment. We used a chin rest to stabilize the gaze of the subject while he looked at a computer screen located 70 cm away from the chin rest. We recorded EOG and EEG activity (Biosemi B.V., Amsterdam, Netherlands), however the EEG activity was not used in the current analysis. We also recorded video-based eye-tracking data (EyeLink 1000, SR Research Ltd, Mississauga, Ontario, Canada), which was used to control the gaze contingent "friends and foes" game (see below).

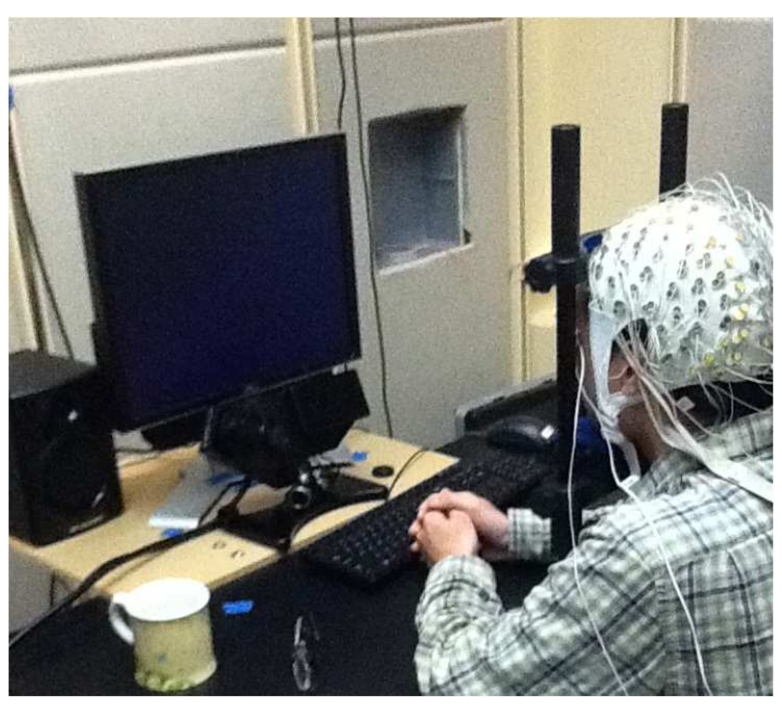

Figure 1: We recorded EOG, EEG (not used in the current analysis), and video based eye-tracking data, while the subject played the "friends and foes" gaze contingent computer game.

Wavelet denoising of EOG data: To remove noise from the EOG signal, we used a wavelet denoising technique [3].

Prediction of gaze position from EOG data: We estimated the filter w that transforms the EOG channel data A into the target positions B by finding the least squares solution of:

$$Aw=B$$

For a set of N fixations, $A \in R^{N\times 6}$ and A[n, i] contains the voltage recorded at the ith EOG channel at the time of the nth fixation, $w \in R^{6\times 2}$ and w[j, k] contains the jth filter coefficient used to predict the horizontal (k=1) or vertical (k=2) component of the target position, and $B \in R^{N\times 2}$ and B[n, k] contains the target position at the time of the nth fixation along the horizontal (k=1) or vertical (k=2) direction.

[1] E. Patten, and L.R. Watson. Interventions targeting attention in young children with autism. The Journal of Speech-Language Pathology, vol. 20, 60-69, 2011.
[2] R.L. Achtman, C.S. Green, and D. Bavelier. Video games as a tool to train visual skills. Restor Neurol Neurosci, 26 (4-5), 435-446, 2008.
[3] S. Mallat. A wavelet tour of signal processing. Academic Press, Waltham, MA, 3rd edition, 2008.
[4] C.A. Joyce, I.F. Gorodnitsky, J.W. King, and M. Kutas. Tracking eye fixations with electroocular and electroencephalographic recordings. Psychophysiology, vol. 39, 607-618, 2002.
[5] M.J. Coughlin, T.R. Cutmore, and T.J. Hine. Automated eye tracking system calibration using artificial neural networks. Comput Methods Programs Biomed. vol. 76, no. 3, 207-20, 2004.

Friends & Foes gaze-contingent game

In designing the game that we will use to train the fixational skills of ASD children we strove for a balance between eliciting sufficiently constrained eye movements for efficient gaze prediction with EOG, and developing a game that will engage ASD children in long fixation sessions. For this we developed the "friends & foes" game, illustrated in Figure 2.

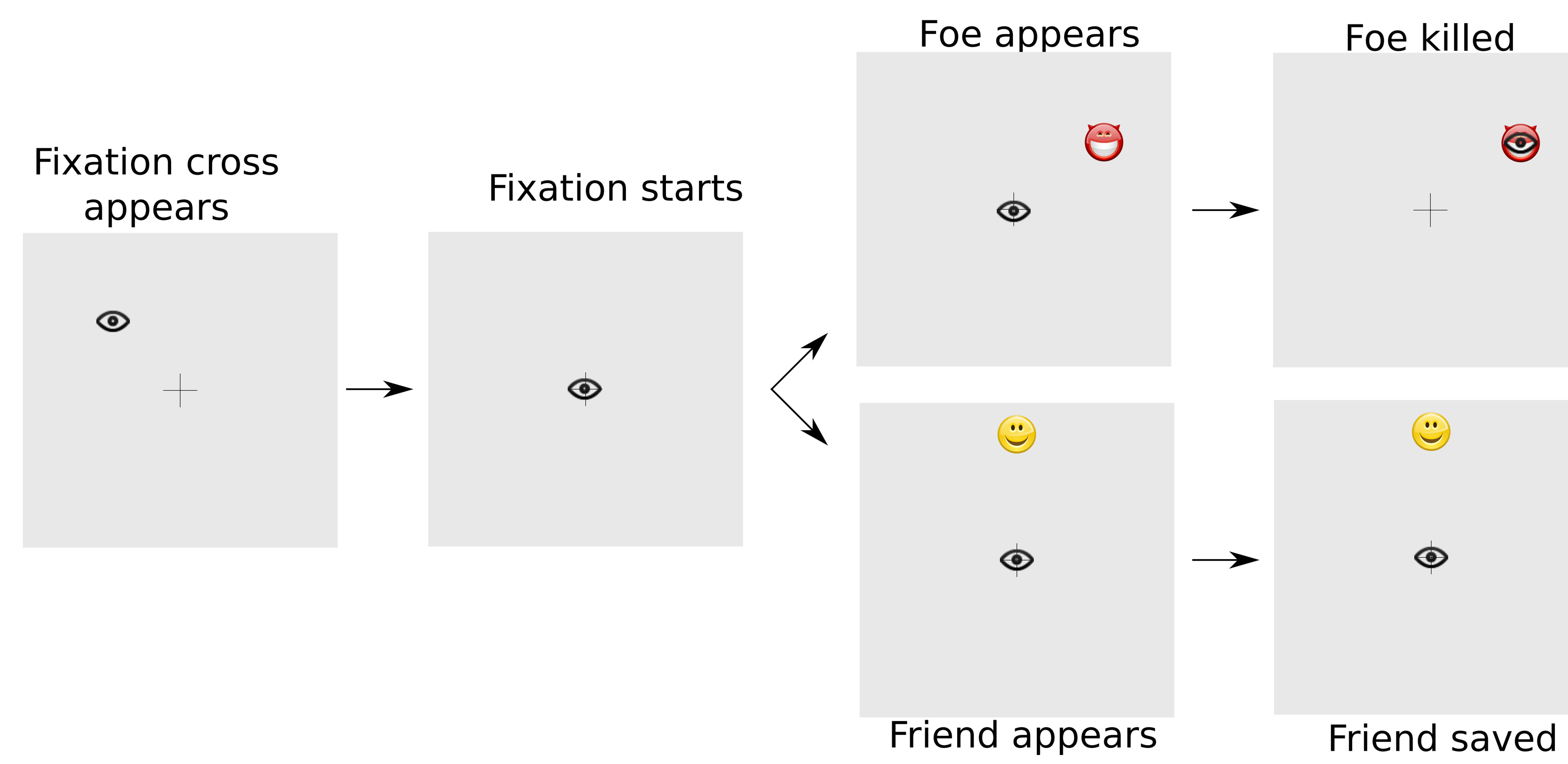

Figure 2: gaze-contingent game used to train fixation skills in ASD children. The goal of the players is to kill the foes with their sight while avoiding killing their friends

Apparent modulation of single-trial activity

Figure 3 summarizes the prediction results. The average error across all target positions was 0.8 and 1.2 degrees in the horizontal and vertical directions, respectively. These figures are comparable with those of previous linear models (e.g., 1.2 degrees horizontally and 2.2 degrees vertically in [4]) and nonlinear models (e.g., 1.09 degrees averaged across vertical and horizontal directions in [5]). Besides estimates for the targets closer to the fixation cross, other estimates of gaze positions appear to be unbiased (i.e., the red targets are located inside the error bars of the mean estimates).

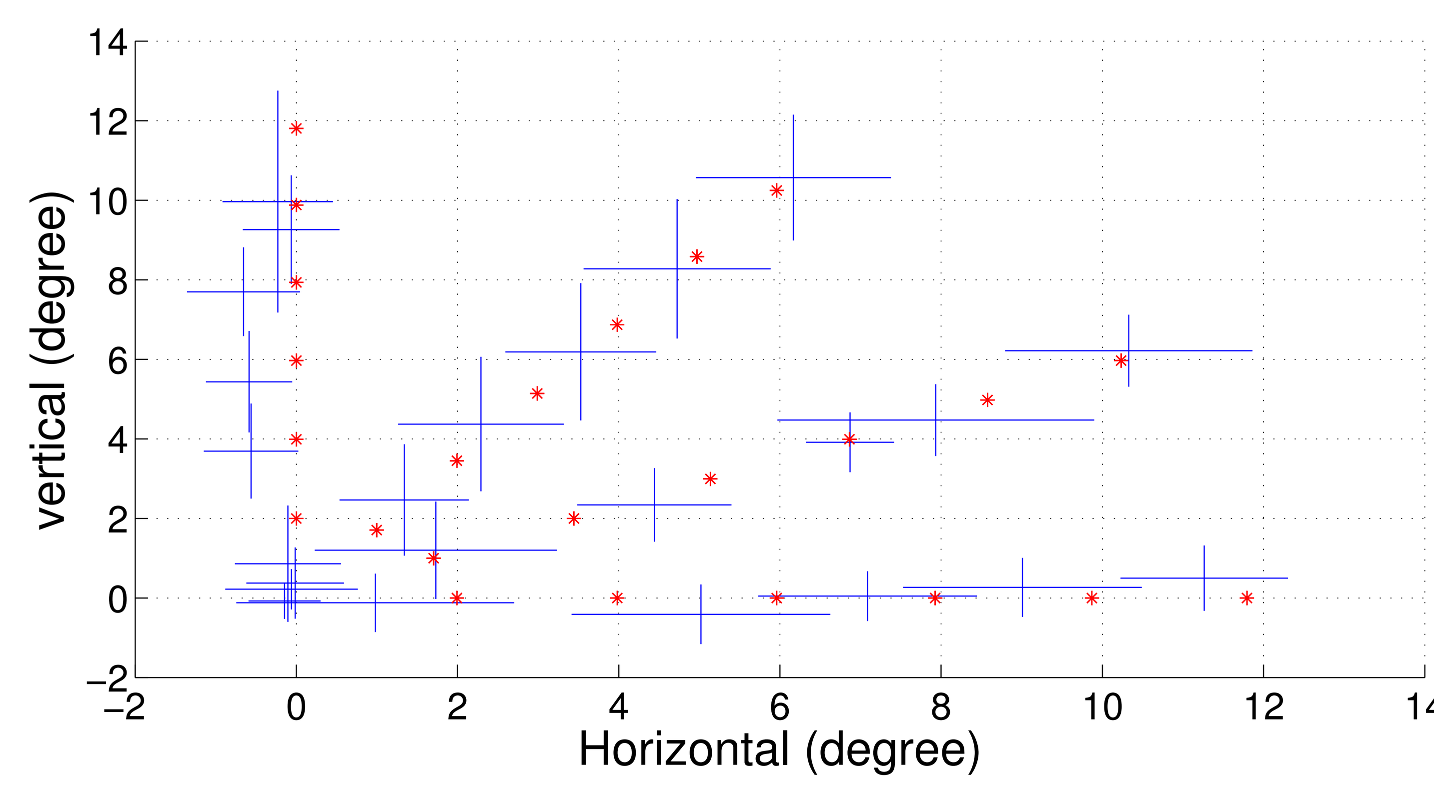

Figure 3: Predictions of gaze position for different target positions. The red marks indicate the positions where targets were displayed. The intersection of the blue lines mark the mean predicted gaze for the corresponding target location. The width of the horizontal and vertical lines represent one standard deviation in the predictions for the corresponding target position.

Conclusions

This project uses new technology to implement a novel concept for behavioral intervention in ASD. Current therapies target social and language behaviors. However, due to the high-level nature of these skills any improvement rarely extends beyond the targeted behavior. The goal of this intervention is to improve basic attention and eye movement skills. Because these basic skills form the foundation for good social and communication skills, training these abilities has the potential to improve a broad spectrum of clinical symptoms, and in young children may affect the course of development. Here we described the initial steps in the construction of a system that will allow children with ASD to improve their fixation skills by playing a computer game controlled by an eye-tracker. Because improving fixation skills would probably require substantial training, it is essential that the system is portable, of low-cost, and easy use. For these reasons the proposed system is based on a portable, dry, and wireless EOG system.