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Attention attraction in an ophthalmic diagnostic device using sound-modulated fixation targets

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ABSTRACT

This study relates to eye fixation systems with combined optical and audio systems. Many devices for eye diagnostics and some devices for eye therapeutics require the patient to fixate on a small target for a certain period of time, during which the eyes do not move and data from substructures of one or both eyes are acquired and analyzed. With young pediatric patients, a monotonously blinking target is not sufficient to retain attention steadily. We developed a method for modulating the intensity of a point fixation target using sounds appropriate to the child's age and preference. The method was realized as a subsystem of a Pediatric Vision Screener which employs retinal birefringence scanning for detection of central fixation. Twenty-one children, age 2–18, were studied. Modulation of the fixation target using sounds ensured the eye fixated on the target, and with appropriate choice of sounds, performed significantly better than a monotonously blinking target accompanied by a plain beep. The method was particularly effective with children of ages up to 10, after which its benefit disappeared. Typical applications of target modulation would be as supplemental subsystems in pediatric ophthalmic diagnostic devices, such as scanning laser ophthalmoscopes, optical coherence tomography units, retinal birefringence scanners, fundus cameras, and perimeters.

1. Introduction

Many devices for eye diagnostics require the patient to fixate steadily on a small point in space for a certain period of time during which the eyes do not move and data from one or more substructures of one or both eyes are acquired. Some diagnostic devices acquire data very fast, within less than a second, while others require tens of seconds. Typical examples would be ophthalmic diagnostic devices for obtaining information from the retina, such as scanning laser ophthalmoscopes, optical coherence tomography (OCT) devices, retinal tomography devices, scanning laser polarimeters, retinal birefringence scanners, fundus cameras, and others. A reliable fixation target is needed in studies of eye position stability in amblyopia ("lazy eye") [1,2]. Other examples would be behavioral or psychological tests where deviations from steady fixation on a target are used as a differentiating measure to detect deviant mental conditions, such as ADHD, for example [3]. Perimeters, eye gaze trackers, and automated refractors all require accurate eye fixation. Some devices for eye therapeutics also require the patient to fixate steadily on a small point in space for a certain period of time during which the eye does not move and is treated, for example with laser ablation therapy for laser vision correction, or laser treatment of structures within the eye.

Some of the above mentioned devices already have an optical subsystem that introduces a fixation target in the visual field of the test subject. For this purpose, typically a constant or blinking light is coupled into the subject's field of view, usually by means of a beam splitter. The blinking light can be a low power laser diode, an LED, or some other source of light. The optical design often requires that the target light be essentially monochromatic, in the best case a laser with a line spectrum, which makes it easier to separate the diagnostic or treatment beam from the target beam by means of optical filters. Laser light is also suitable for manipulation by means of polarization optics. Low-power laser diodes have been used, typically controlled by a square-wave generator of an appropriate frequency [3,4].

Our experience shows that with young pediatric patients (ages 1–5 years), who unfortunately are less cooperative than older children and adults, a monotonously blinking target is not sufficient to retain attention steadily. This often makes it impossible to acquire data over time periods longer than a few seconds. There has thus been a need for improved eye fixation systems.

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Improved fixation has been achieved by means of combining stimulation modalities. It has been shown that the cortex can perform cross-modal multisensory integration leading to enhanced response [5]. Sounds can facilitate visual localization on the basis of spatial coincidence [6]. It has been demonstrated that a sound coming from the location of a visual target facilitates its detection [7]. This has been utilized in a patent for a pediatric retinoscope, where the fixation light was being activated and deactivated while computer-generated sounds were being played [8]. However, there is no study and no published data on the nature of the sounds employed, and how this device performed. In the meantime it was shown that a sound can facilitate visual localization on the basis of temporal coincidence, especially when the visual target has unique dynamics and the sound is synchronized to the target's dynamics, or vice versa [9,10].

While validating our newly developed Pediatric Vision Screener [11–14], we noticed that young patients were more attentive when a favorite tune was played simultaneously with data collection, and even more so when the intensity of the target light was *modulated* with the attention-attracting sound. This inspired us to introduce improvements to the vision screener, as described in the following section.

2. Methods

As a base platform for this study we used the most recent prototype of our Pediatric Vision Screener (PVS), described elsewhere [11,12]. In short, this is a binocular device that employs retinal birefringence scanning (RBS) along a 3° circular path around the presumed center of the fovea and detects characteristic changes in the polarization state of the retro-reflected light in the return path. With no requirement for calibration for each patient, the PVS can precisely detect central fixation and eye alignment, as well as the quality of focus, and thus helps identify risk factors for strabismus and amblyopia in young children. The device uses a second low-power laser diode to provide a point fixation target, which in the earlier version of the prototype was being turned on and off synchronously with a beeper sound with a repetition frequency of 7 Hz [4]. The method proposed here uses appealing sounds to modulate the perceived intensity of the attention-attracting point light target. A computer (CPU) controls the scanning optics and the data acquisition, and simultaneously plays sounds or songs in .wav format, to engage the test subjects (Fig. 1).

The audio signal is simultaneously fed to a modulation circuit that controls the target laser diode, introduced into the visual field by means of a beam splitter. The target laser diode and the scanning laser diode are of different wavelengths, so that they do not interfere with each other spectrally. With good attention attraction, the subject fixates on the point target light over a longer period of time, during which the eye does not move, allowing efficient scanning of the retina. The loudspeaker is positioned in a manner such that the subject perceives it as coinciding with the target. The target laser diode is modulated and is "pulsating" synchronously with the sound. In the present design, which is essentially a subsystem of our Pediatric Vision Screener, we use analog modulation. The modulating sound signal is band-pass filtered (−3 dB at 200 Hz and 2 kHz), rectified, and its envelope is formed, to control a 30 kHz pulse-width modulation (PWM) implemented in analog hardware (Fig. 2).

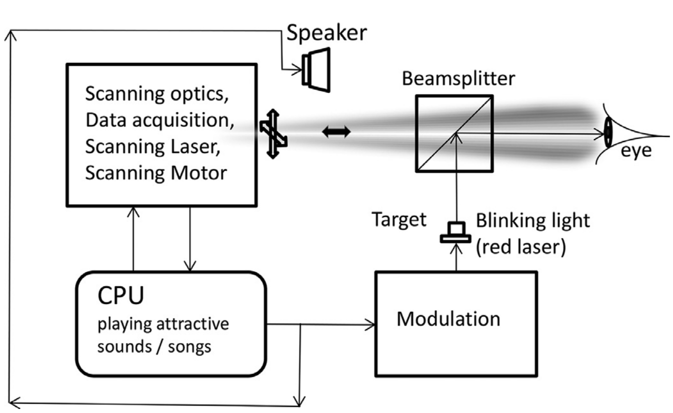

Fig. 1. The attention–attraction arrangement using sound-driven modulation of the intensity of the fixation target, realized as a subsystem of the Pediatric Vision Screener.

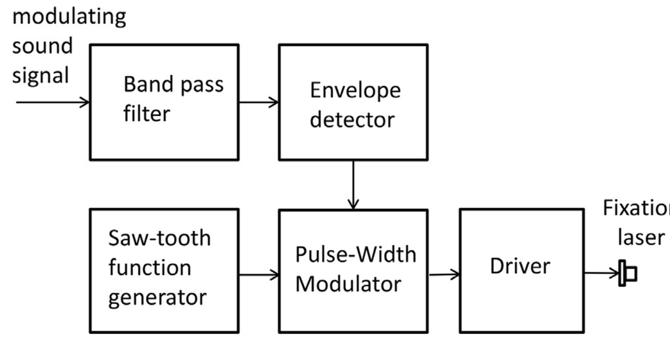

Fig. 2. Pulse-width-modulation (PWM) of the fixation target.

The evaluation protocol followed an approval by the Institutional Review Board (IRB). Twenty-one young subjects (10 boys and 11 girls), ages 2–18, properly consented, were recruited from the patients of the Division of Pediatric Ophthalmology at the Wilmer Eye Institute. Two of the test subjects (ages 2 and 17, respectively) had been diagnosed with constant strabismus. Prior to recording, each child and the accompanying parent were asked to choose from a collection of about 50 favorite children's tunes, gaming sounds, animal sounds, laughter, and several combinations of these. The sounds of choice were all called "tunes," for simplicity. The child was instructed to fixate on the target light, the room lights were dimmed, and RBS signals were acquired and analyzed in two sessions – one with sound modulation, and one with simple blinking and simultaneous beeping at 7 Hz, 50% duty cycle. The order of these two sessions was counterbalanced. For 10 subjects (5 boys and 5 girls), the tune was played first, whereas for the other 11 subjects (5 boys and 6 girls), the session with the simple blinking/beeping came first. Twelve successive recording epochs, each lasting about 1 s, were acquired without a break during each session, and for each epoch the device accurately determined the presence or absence of central fixation for each eye (within about 0.5°). Fixation for the current epoch was assumed when *at least one eye achieved central fixation*. This allowed us to keep the two strabismic subjects in the study. Finally, a success score was calculated for each session and for each method of attention attraction, as a percentage of the epochs with central fixation (at least one eye) over the total number of epochs (12). For example, if during a "beep" session the device detected central fixation (with at least one eye) during three 1 s epochs, the success score for this session was %Beep = 3/12 = 25%.

3. Results

The results are presented in Fig. 3. For each of the 21 patients, the *x*-coordinate reflects the success score for simple blinking/beeping method (%Beep), while the *y*-coordinate represents the success score for the sound-modulated intensity (%Tune). The filled circles represent double occurrences. The straight line at 45° stands