RESEARCH LETTER

Wearable Technology With Head-Mounted Displays and Visual Function

Interest in wearable head-mounted display systems for general consumers is increasing, with multiple models in production.[1] However, their effect on vision is largely unknown. Peripheral visual field is a main component of vision and essential for daily activities such as driving, pedestrian safety, and sports.

Conventional spectacle frames can reduce visual field, sometimes causing absolute scotomas (blind spots),[2] and head-mounted devices have even more pronounced frames. To quantify their effect on visual function, we compared performance on perimetric visual field tests with a head-mounted device vs regular eyewear.

Methods | Three healthy emmetropic or refractively corrected individuals with 20/20 best-corrected visual acuity and normal baseline visual fields were tested in April 2014. Participants used a wearable device (Google Glass, Google Inc), following manufacturer's instructions, for a 60-minute acclimation period. Participants required minor adjustments to optimize screen visibility. To assess obstruction potential, the display prism's position relative to the right eye pupillary axis was graded as (1) over central pupillary axis; (2) above central pupillary axis but inferior to superior limbus; or (3) above superior limbus.

Immediately thereafter, participants underwent 30-2 and 60-4 threshold perimetric (visual field) testing with the Humphrey Visual Field Analyzer II-750i (Carl Zeiss Meditec). Testing was performed first with the device (with software deactivated to avoid distractions), followed by a control frame of similar color and temple width. The University of California, San Francisco, determined the study was exempt from institutional review board review.

To assess how the devices are worn by general consumers, photographs of people wearing the product and facing the camera, obtained from an Internet search conducted on May 1, 2014, were analyzed.[3] The image search included the term *Google Glass*. The full output of images was reviewed, including images posted by companies and individuals. Photographs were assessed for prism position relative to the pupil with the grading system described above.

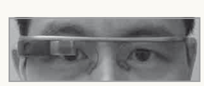
Results | **Figure 1** shows the baseline characteristics of participants. Visual field testing demonstrated significant scotomas in all 3 participants while wearing the device (**Figure 2**; note variations in wearing and head position). In all 3 cases, more than 10° of visual field in the horizontal axis were subtended. Scotoma was absent with control perimetry testing with the regular frame.

For the image analysis, 311 images were found, with 132 eligible for evaluation. The prism covered the pupillary axis in 29.5%, covered the eye but not the axis in 29.5%, and was superior to the limbus in 41%. Therefore, 59% had the prism in a position likely to interfere with vision.

Discussion | To our knowledge, this is the first evaluation of the effect of wearable electronics with head-mounted display on vision. The device created a clinically meaningful visual field obstruction in the upper right quadrant. Defects were induced by the frame hardware design only and were not related to a distracting effect of software-related interference. Image analysis further demonstrated that many people wear the device near or overlapping their pupillary axis, which may induce scotomas and interfere with daily function.

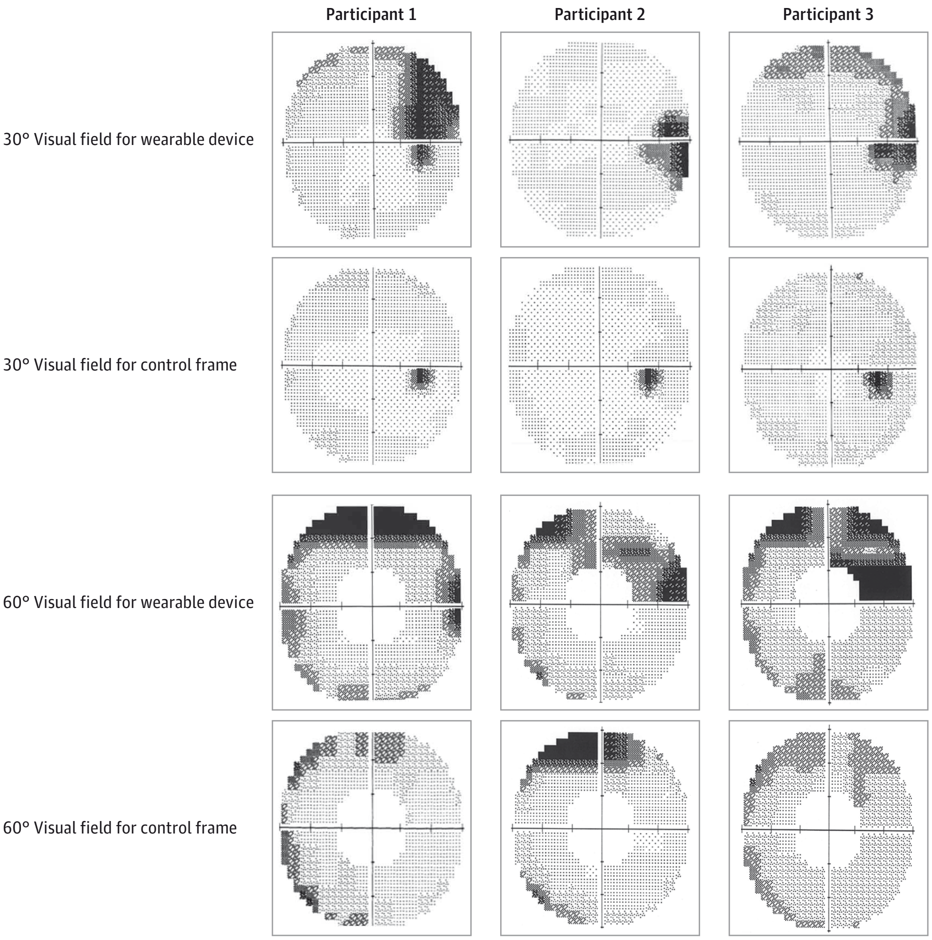
This study is limited by the small number of participants, who may not be representative of all users. Even though the scotomas were easily identifiable, a larger sample is needed to identify factors that influence scotoma size and depth. The

Figure 1. Baseline Characteristics of Participants

	Participant 1	Participant 2	Participant 3
Age, y	40	30	40
Sex	Male	Male	Male
Race	White	Pacific Islander	Asian
Refraction oculus dexter (OD)[a]	Plano	Plano	−6.00 + 0.75 × 90
Best corrected visual acuity OD[a]	20/20	20/20	20/20
Pupillary distance, mm	70	62.5	59.5
Wearable device prism position	Prism placed over the central pupillary axis	Prism cleared the central pupillary axis but was inferior to the superior limbus	Prism placed over the central pupillary axis
			

[a] Indicates the right eye.

Figure 2. Visual Field Testing of 3 Participants



The gray-black areas demonstrate blind spots (scotomas) where the visual field has reduced (darker gray) or no (black) sensitivity to light and visual stimulation. Participant 1 has a pupillary distance of 70 mm and the wearable device scotoma is present in both the 30° and 60° peripheral field test. Participant 2 has a pupillary distance of 62.5 mm and the wearable device scotoma is present in the 30° test but is significantly greater in the 60° test. There is a superior scotoma in the 60° field in the control assessment, likely the effect of the spectacle frame, with an additional temporal scotoma induced by wearable device. Participant 3 has a pupillary distance of 59.5 mm and the wearable device scotoma is present in the 30° test and is significantly greater in the 60° superotemporal quadrant. There is a trace superior defect in the 60° field in the control assessment, likely the effect of the spectacle frame.

study is also limited by the lack of data on other visual parameters (eg, contrast sensitivity) and functional outcomes (eg, driving ability in a simulated setting).

The image analysis was limited to images posted on the Internet and therefore may not be representative. However, many of the images were created by the manufacturer as the intended mode of wearing the device and were clearly in the pupillary axis, whereas others were above the limbus, suggesting variability in how the device is worn and potentially the magnitude of any resulting scotoma.

Additional studies are needed to understand the effects of these devices on visual function, particularly as their use becomes increasingly common.

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Author Contributions: Dr Minckler had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
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Conflict of Interest Disclosures: The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

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