Walking Simulator for Evaluation of Ophthalmic Devices

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ABSTRACT

Simulating mobility tasks in a virtual environment reduces risk for research subjects, and allows for improved experimental control and measurement. We are currently using a simulated shopping mall environment (where subjects walk on a treadmill in front of a large projected video display) to evaluate a number of ophthalmic devices developed at the Schepens Eye Research Institute for people with vision impairment, particularly visual field defects. We have conducted experiments to study subject's perception of "safe passing distance" when walking towards stationary obstacles. The subject's binary responses about potential collisions are analyzed by fitting a psychometric function, which gives an estimate of the subject's perceived safe passing distance, and the variability of subject responses. The system also enables simulations of visual field defects using head and eye tracking, enabling better understanding of the impact of visual field loss.
Technical infrastructure for our simulated walking environment includes a custom eye and head tracking system, a gait feedback system to adjust treadmill speed, and a handheld 3-D pointing device. Images are generated by a graphics workstation, which contains a model with photographs of storefronts from an actual shopping mall, where concurrent validation experiments are being conducted.

1. INTRODUCTION

When a person suffers loss of vision, simply walking down a hallway, or finding the grocery store present a new set of challenges. The mobility and navigation skills that were once taken for granted often need to be completely re-learned. The Vision Rehabilitation Lab at the Schepens Eye Research Institute is studying the impact of visual impairment on mobility and is developing devices to help people regain some of their lost autonomy. People of particular interest are those who suffer from Retinitis Pigmentosa, (RP, affecting 1 in 4,000 people worldwide [1]), and people with homonymous hemianopia. There are about 5 million stroke survivors in the United States [2], and as many as a third of these suffer homonymous hemianopia or hemi-neglect as consequence [3]. These two conditions deprive people of some visual information, but still leave substantial parts of the visual system completely intact and fully functional. When looking straight ahead, a normal sighted observer can see objects more than 90 degrees to the left or right of "straight ahead," and can see about 60 degrees above and 80 degrees below depending on facial structure. People with hemianopia generally have normal vision to one side of the central vertical meridian in both eyes, but have no vision on the opposite side. People with RP progressively lose use of their peripheral vision, but retain central vision through much of the progression of the disease. People are considered legally blind when the horizontal extent of their vision is less than 20 deg in diameter. Most people with less than 10 degrees (diameter) of remaining vision have difficulty with walking tasks [4,5].

The loss of peripheral vision on one or both sides limits the area over which a person can gather visual information at a given instant, and is the strongest visual determinant of reduced mobility. Except when people adopt new eye movement strategies, large parts of a their environment becomes, effectively, invisible. People often experience an increase in the frequency of collisions with objects in their environment, presumably due to either failure to see these objects, or failure to correctly judge the obstacles' relative location and trajectory. We have developed three devices for people with visual field defects and are in the process of evaluating their effectiveness at improving the ability to detect and avoid collisions.

1.1. Ophthalmic devices

The ophthalmic aids we are developing all seek to use "Vision multiplexing" to expand the effective visual field [6]. The devices do this by relocating visual information from a part of the visual field lost to disease to a part of the visual field that is still functioning. These devices all overlay this relocated information on top of the visual information seen with the remaining vision. Multiplexing potentially allows people to monitor a larger visual area without making eye moments but still permit free eye movement for foveal inspection of the detected object.

1.2. Trifield

For people with RP, we have developed a spectacle design (Fig. 1 left) where one of the two lenses is replaced by a pair of abutting prisms that meet at their apices at a vertical seam aligned with the center of the patient's pupil. The other eye is fitted with a standard spectacle lens. When looking straight ahead, three images fall in the remaining visual field: the image of what is "straight ahead" of the subject (seen through the standard lens) and a image containing peripheral views from the left or right of center depending on direction of gaze that are refracted by one of the two prisms to also fall within the subject's remaining central vision. If prism powers are chosen to be greater than the angular diameter of the patient's visual field, with small scanning eye movements, a tripling in effective visual field can be obtained over time (doubling at any instant).

1.3. Peripheral prism

For people with hemianopia, we developed a spectacle designed for displacing visual information across the vertical meridian, from the side without vision to the side with remaining vision. To accomplish this, standard spectacles are fitted with a prism at the top and bottom of one spectacle lens on the side of the visual loss (Fig. 1 center). The prisms (with base to the direction of the visual field loss) are placed above and below the subject's central vision, leaving an unmodified central view of the visual scene. When looking straight ahead however, both the upper and lower visual fields receive visual information from two locations: The eye with the standard spectacle lens sees as it would with normal glasses while the other eye receives information horizontally displaced from corresponding locations above and below center of the blind hemifield. People wearing this device have an effective visual field expansion in the upper and lower periphery that extends into the blind hemifield by the power of the prisms attached to the spectacle lens.

1.4. Peripheral head-mounted display

An alternative device (Fig. 1 right) for people with RP consists of a pair of spectacles with an embedded monochrome video display at the center of one lens [7]. The device also incorporates a miniature forward-facing wide-angle camera mounted on the temple of the spectacles. A pocket-sized image processor converts the video signal from the camera into a edge-enhanced "cartoon" of the environment in front of the wearer. Through this device, the wearer sees the physical world with an overlaid wide-angle view in one eye. The overlaid wide-angle view has the potential to help people detect obstacles over a much wider area than without the device.

Figure 1: Ophthalmic devices to be evaluated in our walking simulator. These devices move visual information into the remaining visual field. From left to right, devices are the Trifield spectacles (Section 1.2), the Peripheral Prism spectacles (Section 1.3) and the Peripheral head-mounted display (Section 1.4).

1.5. Mobility assessment experiments

We are conducting a number of navigation, mobility and visual performance experiments to evaluate the usefulness of our ophthalmic devices. Real-world experiments include an evaluation by an orientation and mobility instructor of walking and navigating in a shopping mall, a traffic gap monitoring task at a complex intersection, and visual search and pointing tasks to evaluate accuracy of locating objects in the extended visual field. To complement these real-world

experiments, we are developing a number of simulated navigation and mobility tasks to further evaluate performance. To this end, we have developed a walking simulator that allows for precise control of a subject's visual environment not possible in real-world experiments while also allowing for more thorough measurement of subjects' behavior as they make use of the devices. In addition, experiments in our virtual environment allow us to test subject's ability to make judgments about obstacles without the risk of actual collisions with those obstacles.

2. APPARATUS

Our walking simulator (Fig. 2) consists primarily of a large video screen situated in front of a treadmill. Subjects walk on the treadmill and are presented with an on-screen view of a simulated environment. Images are generated by a graphics workstation and are projected onto the screen by a high-resolution LCD projector. The walking simulator also incorporates a magnetic tracking system to monitor subjects' head and hand movements during experiments. The head tracking system can be combined with a head-mounted video eye tracking system enabling the recording of subjects gaze point within the simulated environment. In addition, modifications have been made to the treadmill hardware to allow the treadmill to adjust its belt speed to match a subject's gait.
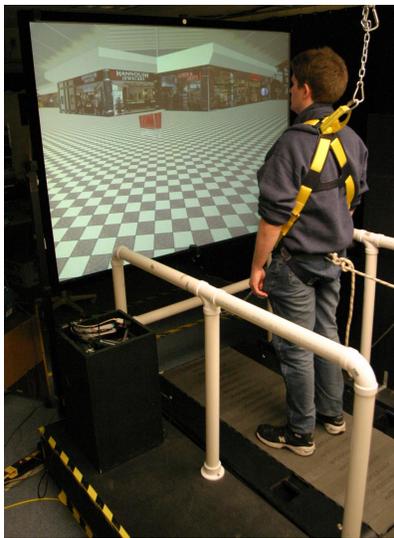

Figure 2: Research subject standing in the walking simulator. The subject wears a safety harness attached to the ceiling for safety and to front and rear anchors to provide balancing forces for active control of the treadmill speed. Subject is shown viewing the model of the Arsenal Mall in Watertown Massachusetts.

2.1. Treadmill

In our simulator, subjects walk on a Woodway Desmo S Treadmill. The treadmill has a motor drive system capable of moving the 22 x 68 inch walking surface at speeds up to twelve miles per hour. In addition, this treadmill can be set to a passive mode, where the belt rolls freely. While other treadmills we tested presented substantial resistance when switched off, the treadmill we selected has a bearing system supporting the belt that dramatically reduces this resistance. This allowed us to run experiments where subjects set their own walking pace by "pushing" the treadmill belt back with each forward step. Early tests with the treadmill revealed that some subjects felt more comfortable walking on the treadmill when it was flanked by wooden staging: When the treadmill was first installed without this staging, the walking surface sat about twelve inches above the floor of our lab. Walking on the treadmill required stepping up onto the belt, which was difficult for some of our subjects. The wooden staging allows subjects to climb up to the height of the belt on solid ground, and then step easily from the staging onto the treadmill. In addition, the staging provides a

visual ground plane that is level with the treadmill belt, reducing the impression that subjects are standing a foot above the floor. Mounted in the staging is a set of removable PVC railings. These railings further facilitate stepping onto and off of the treadmill, and give subjects something to grab on to if they lose their balance during an experiment. For additional safety, we have modified the ceiling above the treadmill to support a suspended nylon harness. Subjects wear the harness while on the treadmill, and the suspending line is tensioned to ensure that the subject will not strike walking surface should a fall occur during walking. The harness also provides mounting points for additional lines used in some experiments to keep subjects centered on the treadmill belt. In experiments where the treadmill is used in non-motorized mode, tethers run between the front of the harness and the PVC railing at the front edge of the treadmill, as well as from the back of the harness to the rear wall of our lab (a few feet behind the rear of the treadmill belt). These tethers anchor the subject at the midpoint of the treadmill, forcing the treadmill belt to slide back as the subject pushes against it during walking.

2.2. Video projection

Images are projected onto a 67 x 50 inch front-projection video screen placed at the front of the treadmill. The screen made from a flexible translucent material that is stretched over a tubular metal armature. The armature is mounted above the wooden staging, placing the screen's center at about eye level for most subjects, just forward of the front edge of the treadmill belt. Images are projected onto the screen by an Epson PowerLite 9100i LCD projector mounted on a stand on the far side of the screen. The projector has a native resolution of 1366 by 1024 pixels, of which we use 1280 by 960 pixels to project an image matching the aspect ratio of our screen. We chose to use a projected display instead of the head-mounted displays often used for virtual environments research because of the physical constrains head-mounted displays impose. Head-mounted displays have either a small field of view—too small for our application—or heavy optical systems to expand this field. In addition, the optics in head-mounted displays are usually close to the subject's eyes, which precludes the use of our ophthalmic devices.

2.3. Head and hand tracking system

Head and hand tracking are performed with an Ascension Flock Of Birds magnetic tracker (Ascension Technology Corporation, Burlington, VT). Our configuration consists of two cable-mounted location and orientation sensors, and an Extended Range Transmitter. Sensors are wired to control electronics in cabinets on the staging to either side of the treadmill, and the Extended Range Transmitter, a one-foot cube, is situated on a wooden tower two feet to the right of the treadmill. The magnetic tracking system works by generating oriented magnetic fields in the transmitter, and sensing those fields with coils in each of the sensors. The transmitter contains three perpendicular coils, each energized independently in a repeating sequence. Each of the sensors also contains three perpendicular coils, and senses the strength of the magnetic field in each dimension as each coil in the transmitter is energized. By comparing relative strengths of the generated fields, the tracking system can derive the orientation of each sensor relative to the transmitter. By measuring the absolute strength of the fields, distance between transmitter and each sensor can be found.

The magnetic tracking system measures sensor location and orientation with precision acceptable for our application (measurement noise rarely exceeds $1/10^{th}$ of an inch or $1/10^{th}$ of a degree), but the measurements exhibit spatial distortion that varies in magnitude and direction over the usage envelope. This distortion is usually attributed to the presence of metallic objects in the vicinity of the tracking hardware that interact with the generated magnetic fields used for tracking. We use a calibration apparatus to measure distortion in our tracking environment. We then apply a polynomial correction function (based on the calibration measurements) to all data from the tracking system [8,9].

The magnetic sensor used for tracking head movement can be mounted on an adjustable headband worn by the subject. We mounted the sensor on a Lego brick and use this brick to attach the sensor to the headband. The modularity of the Lego system allows us to quickly and securely attach our head-tracking sensor to the headband, or directly to a variety of head-mounted devices including our eye-tracking headgear. The sensor used for tracking hand movement is attached to a Logitech TrackMan Live wireless mouse (Fig. 3). When used in conjunction with the wireless mouse, subjects can point to objects in the virtual environment, and respond with button presses all from the same device.
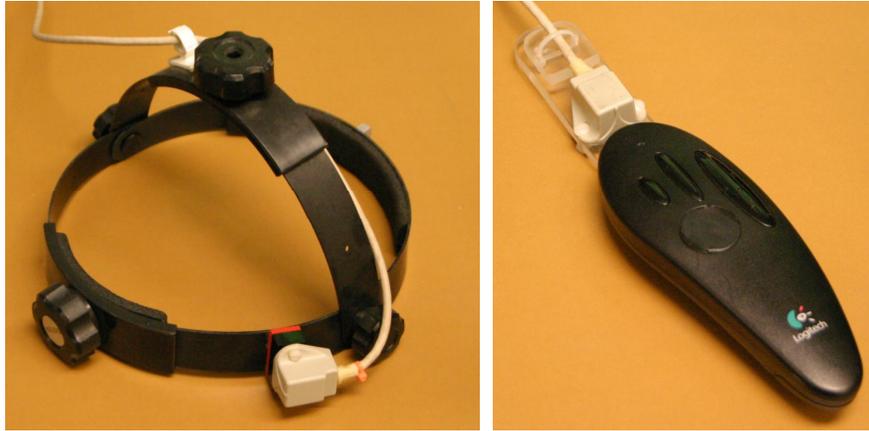
Figure 3: Magnetically tracked headband and pointing device. Head tracking allows for adjustment of virtual camera to generate images correctly for subject's eye position. Handled pointing device incorporates a magnetic tracker and a wireless mouse to record pointing direction and response button presses.

2.4. Eye tracking system

We use an ISCAN head-mounted infrared pupil tracking system (Fig. 4) for experiments requiring monitoring of a subject's gaze. The ISCAN optical system consists of a downward-facing camera that images the front of the subject's eye as reflected in a dichroic mirror. An off-axis infrared LED attached to the camera illuminates the eye, but is invisible to the subject. The camera, LED and mirror are mounted on a plastic visor, placing the camera above the subject's eye, just out of view. The mirror sits just in front of the subject's eye, and reflects the infrared light from the illuminated eye up to the camera. Since the dichroic mirror does not reflect visible light, the subject has an unobstructed forward view through the mirror.

The video signal from the head-mounted eye camera is relayed to a dedicated computer containing specialized hardware for processing the eye image. This system locates the pupil by finding a dark contiguous circular region in the video image. Location of the pupil center within the video frame is approximately linearly related to eye position on a tangent screen [10]. The location of the pupil center is relayed to the main simulation workstation where angle of eye relative to the head is computed. When combined with information from the head tracking system, gaze point on the screen can be found [11,12].

Figure 4: Eye tracking headgear with attached magnetic tracker. Eye tracking system images subject's pupil with a visor-mounted infrared camera via dichroic mirror positioned in front of subject's eye. Eye tracking is integrated with magnetic head tracker allow computation of gaze point on screen.

2.5. Treadmill speed feedback system

In experiments where we used our treadmill in non-motorized mode, we discovered that despite the relatively low friction of the treadmill we chose, propelling the treadmill throughout long experiments was tiring for some subjects. In addition, we discovered that the mass of the treadmill belt itself made starting the belt from rest, or slowing it to a stop more difficult than commencing or discontinuing natural walking on solid ground. Although we had hoped that subjects might be able to slow down or stop upon encountering obstacles in the simulated environment, we found that subjects chose to maintain a consistent pace throughout experimental sessions. We suspect this was because changing speed required more effort in an already tiring task. To give our subjects easier control over their walking pace, we modified our treadmill to adjust belt speed based on subject position. We built a speed adjustment system that interfaces with the treadmill drive system through an Atmel 8515 microcontroller running custom software. The microcontroller also monitors tachometer signals from the treadmill drive electronics, and interfaces with our simulation computer via a RS232 serial connection. A software program on the main simulation computer implements a simple control loop incorporating proportional, integral, and derivative feedback from the head tracker: The control loop attempts to keep the head tracking sensor above the center of the treadmill belt, updating treadmill speed settings 120 times each second. As a subject on the treadmill walks faster, he or she advances farther forward on the belt, causing the feedback system to increase belt speed. Similarly, slowing pace causes the system to decrease belt speed. Although such a system does not match the forces a person experiences during natural acceleration and deceleration, it allows subjects to walk and to vary their walking speed without the effort of physically pushing the treadmill belt.

3. SIMULATED ENVIRONMENT

Images for the walking simulator are generated by custom software running on an Evans and Sutherland SimFusion 4000q graphics workstation. The software uses World Toolkit, an OpenGL-based computer graphics software library, to generate images of a simulated 3D environment. We chose the SimFusion graphics workstation after pilot subjects reported being distracted by flickering edges of objects on the screen. The SimFusion system is accelerated to perform full-scene antialiasing at no extra performance cost on a 1280 by 960 framebuffer. This antialiasing eliminates most of the flicker artifacts we were experiencing. Images are generated at a rate of 60 frames per second, and appear on the projection screen approximately $1/30^{th}$ of a second after being requested from the graphics hardware due to buffering delays in the projection system.

As we are interested in testing how our subjects detect obstacles in busy, cluttered environments, we chose to develop a 3D model of the interior of a shopping mall for our simulated walking experiments. Software was developed to facilitate the description of "obstacles" in the shopping mall environment, allowing for these objects to be placed in different locations throughout the environment. The software also provides a means for assigning to these objects a number of behaviors exhibited by real-world obstacles.

3.1. Shopping mall model

The simulated shopping mall environment used in several of our mobility experiments was modeled after the Arsenal Mall in Watertown, Massachusetts, where concurrent real-world experiments are being conducted. Our simulated shopping mall was created by digitizing blueprints of the shopping mall building, and constructing a computer model of the building using a number of computer-aided design tools. Photographs were taken of all storefronts in the Arsenal Mall, and texture-mapped to corresponding surfaces on the 3D model.

Figure 5: Overview of 3D model of shopping mall modeled after the Arsenal Mall in Watertown Massachusetts. Model was constructed from blueprints of shopping mall and from photographs of storefronts.

As the complete model of the arsenal mall contains a number of different sections and levels, which make experimental design more complicated, we also constructed a simplified "infinite corridor" model for some of our experiments. This infinite corridor is a simple rectangular 300-meter-long hallway populated with storefront images on the walls, and with a floor and ceiling similar to those found in the full 3D shopping mall model. This corridor was constructed so that copies of the model could be placed end-to-end, providing the illusion of a continuous hallway. When used in experiments, new copies of this hallway section are created in front of the subject, just beyond the view horizon, and copies behind the subject are removed when they pass out of sight.

In addition to architectural models, several 3D models of "obstacles" to be placed in the shopping mall were constructed using the same software. Obstacle models include a shopping cart, a trash barrel on wheels, a bundle of helium balloons, and a set of simple simulated humans.

3.2. View geometry

During experimental sessions, the main simulation computer continuously generates views of the 3D shopping mall model for display on the screen. A virtual camera is placed inside the 3D shopping mall model and the simulation software controls the location and orientation of this camera. The location and orientation within the scene of the virtual camera represents the placement of the subject's viewpoint within the simulated environment. The virtual camera's facing direction within the simulated environment corresponds to the direction normal to the projection screen (the long axis of the treadmill). Depending on experimental requirements, the virtual camera can move automatically, it can move in response to movement of the treadmill, or the head tracker, in response to button presses on the handheld controller, or some combination of these. When the simulation is set to move the camera following treadmill motion, before drawing each image, the simulation software queries the treadmill control unit and determines how far the treadmill has moved since the last query. The camera is advanced in its facing direction by the distance measured by the treadmill. Similarly, when the simulation software is configured to update the camera in response to head tracker movement, the virtual camera is translated—before the rendering of each image—by the measured translation of the head tracker: A forward translation of the head tracker (towards the screen) results in the movement of the virtual camera in its facing direction. Sideways or vertical movements of the head tracker translate the virtual camera perpendicular to its facing direction. Rotational movement of the camera is either automatic (for experiments where subjects traverse a pre-determined path) or can be triggered by button presses on the handheld controller. Experiments using this handheld controller allow the subject to rotate the viewpoint either to the right or left using buttons at the sides of this device. A third button on the controller can be used for experimental responses, such as subject's detection of an obstacle.

3.3. Experiment control infrastructure

We developed a set of software libraries for quickly specifying new experiments in the virtual environment. These software libraries provide functionality for constraining the subject's movement through the environment (for example, along a set path). The libraries also provide tools for specifying the placement and movement of obstacles in the environment.

Software written to manage subject movement through the virtual environment can allow simple "free" movement or can be configured with a variable number of constraints. When configured for free movement, subjects can move throughout the environment, controlling direction and speed of movement with the handheld controller and treadmill respectively. In this mode, the simulator monitors the subject's virtual location within the environment and maintains the viewpoint above the floor to match the height of the subject's eye above the treadmill. Our virtual environment has sections at different elevations (with ramps transitioning between them) and the height-matching system allows subjects to smoothly traverse these ramps without changing viewpoint height above the virtual floor. In addition to tracking distance from the floor, the software can be set to monitor the subject's virtual location with respect to the bounds of the virtual environment. This portion of the software uses a simplified model of the perimeter of the shopping mall corridor to quickly test whether subject movement requested by treadmill or head tracker movement would allow the subject's viewpoint to pass outside the shopping mall model. If a subject attempts to walk through a wall or storefront window, the viewpoint stops just inside the shopping mall perimeter.

A software library was also written to specify the placement and behavior of obstacles in the walking environment. This software library employs object-oriented design principles, giving each obstacles a set of properties (such as location in the environment) and a set of actions each obstacle is capable of performing (such as appearing or disappearing). The obstacle software library supports specification of obstacle parameters either through a C programming language interface, or through a simple text file. We generated obstacle specification text files with scripts written in higher level programming environments (such as Python or Matlab) to allow for rapid development of new experiments.

The obstacle specification software library allows for a number of different behaviors that can be assigned to obstacles. These behaviors were chosen to simulate some of the types of interactions people might have with real-world obstacles, as well as some "impossible" obstacle behaviors (such as appearing out of thin air). Our simplest experiments require obstacles that appear when the subject passes within some radius of a point in the environment, and then disappear after some time interval. When obstacles appear, they can be set to "dissolve" in, fading from being fully transparent to fully opaque over a tenth of a second. They can likewise be set to fade out instead of simply disappearing. This behavior was used in a number of our collision detection experiments, where subjects had only one second to survey obstacle location within the environment: As a subject walked down the virtual corridor, stationary obstacles would appear at some location on the floor in front of the subject and then disappear shortly thereafter. In addition to stationary obstacles, the obstacle software allows for specification of moving obstacles. These moving obstacles can be triggered similarly to the stationary obstacles described above, appearing when the subject approaches. Moving obstacles however, can have a second trigger distance, specifying how close the subject can approach before the obstacle begins moving. (If these two distances are the same, the obstacle will immediately start moving when it appears.) Moving obstacles also can be specified to move in a fixed direction within the virtual environment (e.g. North), can be specified to move in some direction relative to subject location at the time of triggering, or can be set to move in a direction relative to an extrapolated collision course with the subject. A third method for specifying moving obstacles removes the need for specifying the absolute location of obstacles within the environment. Instead, obstacles are specified by their passing distance from and angle relative to the subject's viewpoint, and can be triggered on a schedule, or by the experimenter. This third method is best suited for experiments where subjects are free to move throughout the environment but still allowing for exact specification of the geometry of encounters with obstacles.

4. EXPERIMENTS

Our walking simulator has been used to conduct several control experiments in preparation for its eventual planned use of replicating real-world mobility experiments.

4.1. Perceived physical size

In the first experiment performed using our walking simulator, we investigated subjects' perception of obstacles in a constrained walking scenario.

In this experiment, we sought to measure subjects' perceived safe passing distance when encountering stationary obstacles while walking. We also sought to examine how consistently normally sighted subjects evaluated potential collisions with obstacles. In this experiment, subjects walked on the treadmill, progressing along a pre-determined "zig-zag" path down the length of our infinite corridor model. About halfway along each straight segment of the walking path, subjects were presented with a stationary obstacle (a 2 meter rectangular prism with the image of a person applied to the faces), which was visible for one second before disappearing. After the obstacle disappeared, subjects could walk a few more meters before forward progress through the corridor was stopped. Upon stopping, subjects responded either "yes," if they believed they would have collided with the virtual obstacle had they continued walking in the same direction, or "no" if no collision would have occurred. After responding, the subject's viewpoint was rotated slightly (to discourage subjects from basing their responses on architectural cues) and then forward movement was again allowed, beginning a new obstacle presentation trial. Subjects were presented with 128 obstacles placed over a range of distances from the subjects' path. Obstacles were either five or fifteen meters in front of subjects when they appeared.

In this experiment, we found that, for the most part, subjects responded consistently for obstacles appearing at the same location relative to the walking path. Surprisingly, we found no significant correlation between physical measurements of subject's body dimensions, and the distance from obstacles at which subjects reported anticipating collisions. However, when wearing an apparatus that increased their size, the subjects altered their perceived safe passing appropriately. In addition, we found that subjects responded more consistently to objects that appeared five meters down the corridor than to objects appearing fifteen meters ahead.

4.2. Control experiments

Several additional experiments are being conducted to examine the impact of different virtual environment configurations on subject's responses about potential collisions [13]. These experiments closely followed the design of the physical size experiment, but additional features of the virtual environment are selectively activated in a series of experimental sessions with the same subject to see how these features impacted responses. In the Physical Size experiment, treadmill speed was fixed for each subject based on prior real-world walking speed measurements. We examined the impact of allowing subjects to instead self-propel the treadmill, or allowing subjects to complete the experiment while standing in place, viewing the simulation passively. The Physical size experiment was conducted without head tracking. To test our head tracking system, we conducted several experiments to examine the value of having the image generated by the computer exactly tailored to the location of the subject's eye. We ran experimental sessions both with and without head-tracked viewpoint adjustment, and also ran sessions with the virtual camera configured for a subject standing 0.6 meters to the side of the treadmill, regardless of actual subject location. In these experiments, we found no difference in performance between motorized and non-motorized treadmill conditions. Subjects made better decisions standing still on the treadmill than when physically walking. We also found that with an intentionally shifted virtual camera, subjects' responses were biased to one side.

4.3. Simulated peripheral vision loss

Another experiment being conducted employs the head and eye tracking system to limit the subject's view of the visual scene to a small circle centered at the point of gaze [14]. This experiments simulates the loss of peripheral vision experienced by people with RP. Subjects were presented with obstacles while having vision restricted to 5, 10 or 20 degrees, and performance was compared to the unrestricted vision condition. Preliminary results show that, as one might expect, vision restriction causes subjects to fail to detect obstacles with increasing frequency as the visible area is

reduced. Interestingly however, subjects seem to be able to make decisions about obstacles with no less accuracy than with full vision, provided that the obstacle is seen in the first place: Even when subjects only saw the obstacle very briefly, they appeared to be able to make accurate determinations of the risk of collision. This implies that subjects may be responding to the visual direction of the obstacle, and not to the movement of the obstacle relative to its surroundings.

ACKNOWLEDGEMENTS

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