Looming Silhouette: An Approaching Visual Stimulus Device for Pedestrians to Avoid Collisions

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ABSTRACT
We are exposed daily to the risk of collision at numerous blind intersections. To avoid the risk of collision, we propose a system that elicits an "approaching sensation" by presenting a visual stimulus. Possible factors for the approaching sensation are the "expansion" and "motion" of a silhouette. We compared the effects of these two factors on the approaching sensation and found that to elicit an approaching sensation, the expansion factor is important, and the motion factor has a certain effect in alarming pedestrians. On the base of this result, we produced a system that presents an expanding and moving silhouette of an approaching pedestrian to the pedestrians user.

Categories and Subject Descriptors
H.5.2 [**INFORMATION INTERFACES AND PRESENTATION**]: User Interfaces - *User-centered design*

General Terms
Design, Human Factors

Keywords
"Approaching sensation", Collision avoidance, Peripheral vision field

1. INTRODUCTION
We are exposed daily to the risk of collision at numerous blind intersections, both on the street and inside a building. To avoid such risk, various devices have been developed.

One familiar example is a curved mirror, which eliminates the blind area through optical reflection. However, to obtain information from the small reflection image, pedestrians must look directly at the mirror. It also requires a mental load to process the mirror-reversed image [1].

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Electrical devices have been employed to solve the latter problem. NaviView is one example of using Augmented Reality (AR) technology to see through a corner with a head-up display, which displays an image from surveillance cameras at an intersection [2]. Although these technologies are promising for driving cars, they are not applicable to pedestrians, who can neither carry such a device, nor be instructed to look at the device from time to time.

2. METHOD
This paper focuses on pedestrian collisions at a corner. Although there are no statistical data available, collisions between pedestrians is a potential risk at locations such as emergency hospitals, where people must move quickly at times. Furthermore, the established knowledge can be extended to the collision between a pedestrian and car, in which case the pedestrian is notified of the approaching danger.

Collision avoidance for pedestrians differs from that for cars in several respects: (1) it is not acceptable to require the pedestrian to carry a device, (2) it is not acceptable to require the pedestrian to look directly at, for example, a curved mirror, and (3) the information presented should be as "intuitive" as possible since the pedestrian will not be trained.

To satisfy the three above requirements, we propose to present warning information on a wall beside the pedestrian (Figure 1). The first and second requirements are satisfied because the information is presented on the wall and it is large enough to be perceived in the peripheral vision.

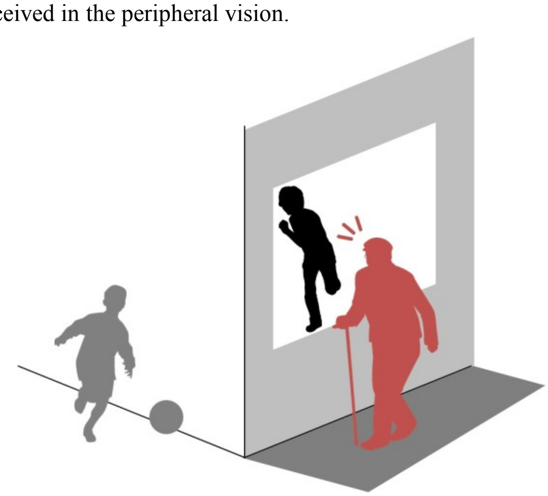

Figure 1. Image of the system

The main research question is thus how to achieve the third requirement, intuitiveness. Note that a simple flashing light is not considered to be intuitive, because untrained pedestrians cannot grasp the meaning of the light, although the light might alert the user in the sense of surprising them.

To realize intuitive presentation, we focus on a visual “approaching sensation”. For example, people seeing a ball coming close to them feel an approaching sensation, and avoid the ball involuntarily. This reflex can be observed for an infant [3], and that it is thus considered an intuitive cue for pedestrians.

The essence of the approaching sensation has been studied in previous works. Gibson et al. reported that Rhesus monkeys frequently take evasive action only if they are presented with an “expanding silhouette” [4]. Therefore, by presenting an expanding silhouette, we may be able to provide pedestrians with an approaching sensation.

Our situation differs in that pedestrians themselves move. Therefore, there might be two visual cues, one being expansion, and the other motion. This paper compares these two factors, and gives the design principle for a warning signal for pedestrians.

3. EXPERIMENT: Comparison of Expansion and Motion

As discussed in the previous section, the key factor for the approaching sensation is the “expansion” of a silhouette. On the other hand, "motion" of the silhouette cannot be ignored, because the observer is also walking in our case.

We consider a person approaching from behind a corner (who we refer to as an “approaching person”). If the corner is translucent, the walker should see a “silhouette” of the approaching person on the wall. For example, if the approaching person starts from the same distance from the corner and moves at the same speed, the person’s silhouette should appear the same relative position and expand in the user‘s field of view (Figure 2 left). On the other hand, if the starting position or speed differs, the silhouette moves relatively in the user’s field of view (Figure 2 right).

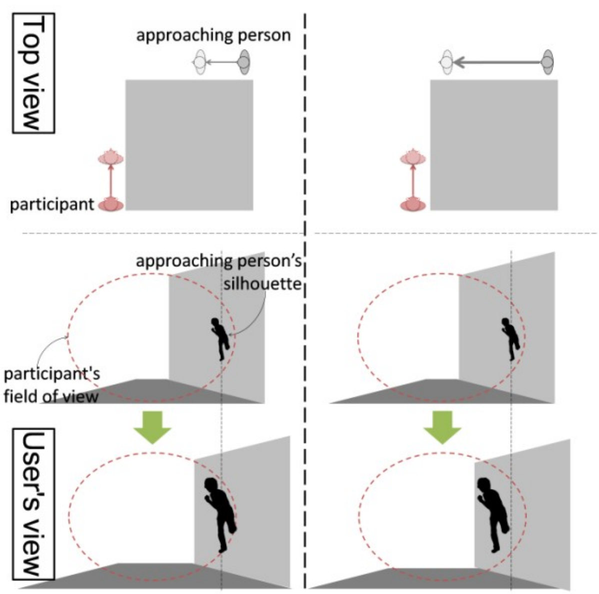

Figure 2. Appearance of an approaching person’s silhouette (left: same velocity and same start position, right: different velocity)

In other words, for the approaching sensation at the corner, expansion and motion seem to be relevant factors. We compared the effects of these two factors on the approaching sensation.

3.1 Optical Stimulus

In this experiment, we presented two factors (expansion and motion) independently or combined (Figure 3).

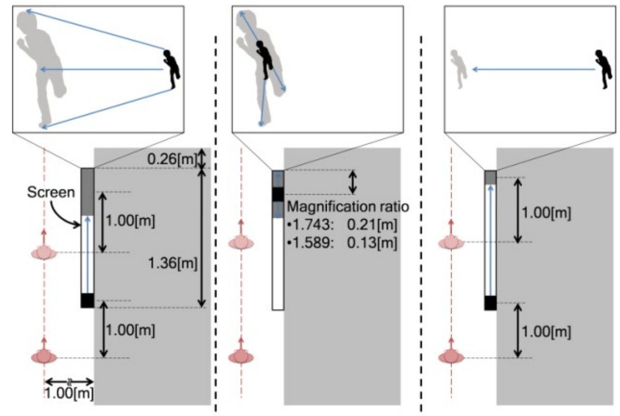

Figure 3. Visual stimulus (left: expansion and motion, middle: expansion, right: motion)

When we there is an expansion factor, the visual stimulus expands around a point on the screen (Figure 3 middle). When there is a motion factor, the visual stimulus moves along with the participants (Figure 3 right), which means that the visual stimulus does not move relatively for the participants.

For the expansion factor, we used two magnification ratios, 1.743/m and 1.589/m (where A/m means that the silhouette expands A times when the participants moved 1 m). These ratios were tested in preliminary experiments and it was confirmed that the former elicits the approaching sensation, while the latter does not. In this experiment, we presented five conditions as listed in Table 1.

Table 1. Experimental conditions

	Presented Factor	Magnification ratio[/m]
1	Expansion & Motion	1.743
2	Expansion & Motion	1.589
3	Expansion	1.743
4	Expansion	1.589
5	Motion	-

We used the shape of the pedestrian’s silhouette as a visual stimulus. The silhouette moved and expanded, while the limbs of the silhouette did not move.

During the experiment, we measured the moving distances of the participants with a range sensor (SHARP, 2Y0A710F, effective range of 1.0-5.5 m), and the visual stimulus was expanded or moved according to the distance. For example, if the visual stimulus included a motion factor, we moved the visual stimulus at the same speed as the participant, so that it always appeared at 45 degrees in the right oblique view of the participants.

3.2 Procedure

Figure 4 shows the environment of the experiment.

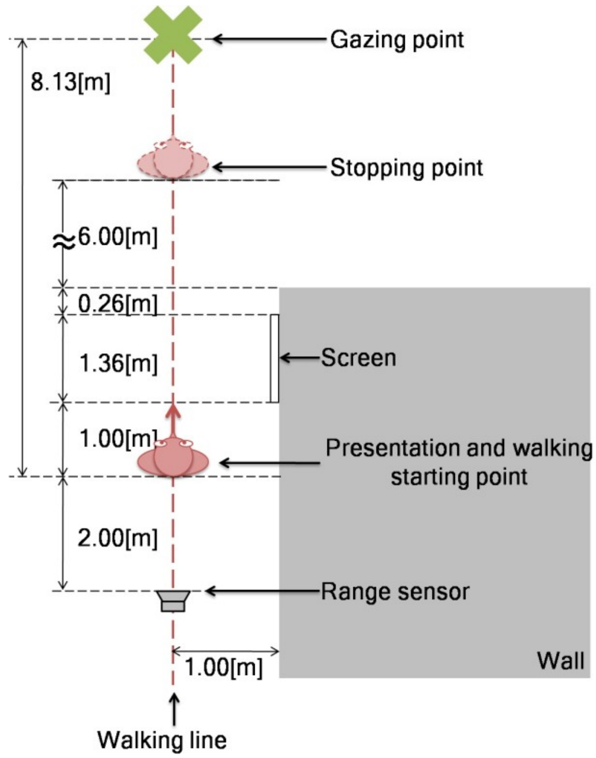

Figure 4. Experiment environment

We projected the visual stimulus on a white screen on a wall using a projector (NEC, WT610) with 640 × 480-pixel resolution. The size of the screen was 1.36 m × 1.03 m, and the viewing angle from the walking line was 53.6 deg × 45.8 deg. To keep the participants looking forward (i.e., to present the visual stimulus in the participant's peripheral visual field), we set a gazing point in front of the participant, 8.13 m from the starting point and at 1.50 m height. The range sensor was 2.00 m behind the starting point, at 0.98 m height. The illumination intensity was (44.6 ± 0.6) × 10 lux and the brightness of the screen was 266.0 ± 0.6 cd/m^2. The frame rate of the visual stimulus was 30.0 fps.

The participants started walking from the starting point and stopped at the stopping point. Before the experiment, we asked the participants not to change their walking speed intentionally throughout the experiment. After the participants stopped, the experimenter asked the participants if they felt an approaching sensation. Furthermore, to estimate the emotional reactions included by the stimuli, the experimenter asked the participants if they were "alarmed" (In our preliminary experiment, we tried other values such as the skin conductance response but there was no detectable change of in value.).

Five trials were conducted for five conditions (Table 1), giving 25 randomized trials in total for each participant. Five participants, four male and one female and 22 and 23 years of age, participated in the experiment.

3.3 Results and Discussion

The results are shown in Figure 5 and Figure 6. The vertical axis shows the average response ratio for the approaching sensation or feeling of alarm.

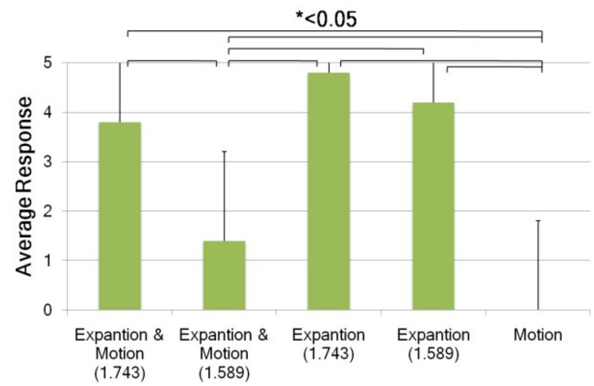

Figure 5. Response ratio (approaching sensation)

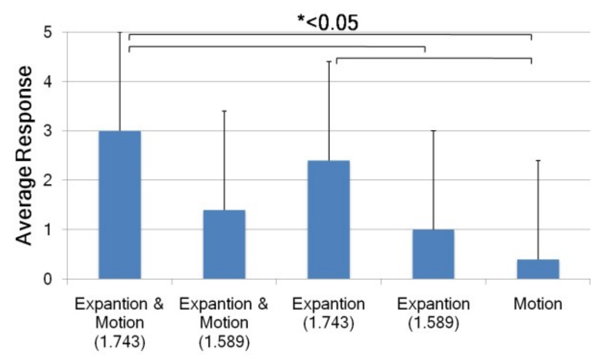

Figure 6. Response ratio (feeling of alarm)

The approaching sensation was elicited when the stimulus included an expansion factor. The sensation became clearer with greater expansion. The motion did not seem to effect the sensation.

The feeling of alarm was also elicited when the stimulus included an expansion factor. Although there was no significant difference, the motion seemed to enhance the feeling of alarm.

These results indicate that to elicit an approaching sensation, the expansion factor must be included in the visual stimulus. The motion factor seemed to have a negative effect on the approaching sensation, but it also had a positive effect on the feeling of alarm. Note that the "motion" in this experiment was that the visual stimuli appeared to have the same relative position in the user's field of view.

4. IMPLEMENTATION

From the result of the experiment, a device to elicit both the approaching sensation and feeling of alarm with expanding and moving visual stimuli was implemented.

4.1 System Overview

The proposed visual stimuli device consists of inorganic electro-luminescence (EL) sheets (Lumitechno, EL-A3-W). The dimensions of the device were width of 1.31 m, height of 0.97 m on the left side and height of 0.22 m on the right side (Figure 7).

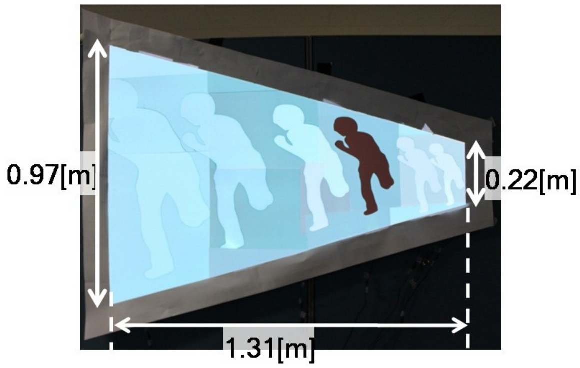

Figure 7. Device image (front view)

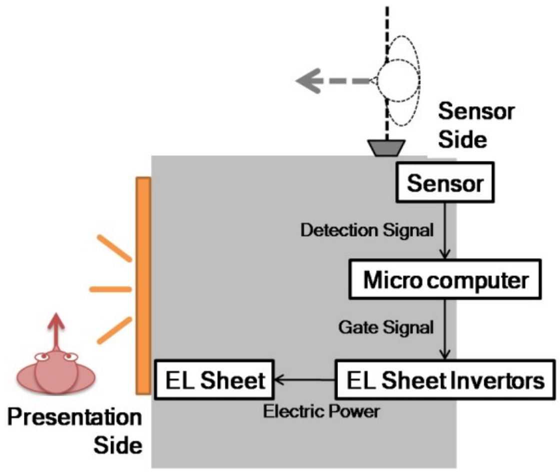

Figure 8. System diagram (top view)

The EL sheet was cut to the shape of pedestrians, with six different sizes. The cut-outs were arranged in ascending size from right to left avoiding overlap. The background was also covered with an EL sheet.

By turning on all EL sheets and turning off one pedestrian shape, we can present a silhouette, just like in the experiment (Figure 8). By changing the turned-off pedestrian shape from right to left, we present expanding and moving silhouettes as we presented in the experiment. These visual stimuli are presented when a sensor on the opposite side of the corner detects an approaching person.

The frame rate of the silhouettes is 6.09 fps if we assume the pedestrian's speed to be 1.33 m/s (which was an average value obtained in the previous experiment). This seems quite slow, compared with the experiment setup (30 fps). However, we confirmed with a preliminary experiment that this change in frame rate does not affect the approaching sensation. The silhouette's magnification ratio was set equal to the magnification factor that we used in the experiment (1.743/m).

5. CONCLUSION

To avoid the risk of collision at numerous blind intersections, we proposed a system that elicits the approaching sensation by presenting a visual stimulus. We compared the effects of two factors, expansion and motion, on the approaching sensation. The result showed that the expansion factor is important for the approaching sensation while the motion factor has a small effect on the feeling of alarm. On the basis of these results, we made a device that presents an expanding and moving silhouette of a pedestrian that considers the participant's motion.

In this paper, we treated the expansion and velocity independently. Originally, however, these two factors are not independent variables but both dependent on the "route" of the approaching pedestrian. There is the possibility that not only are we affected by expansion and motion, but we also calculate the route and possible risk of collision. We need to verify a relationship between the route and approaching sensation.

As mentioned in section 2, if the purpose of the system is to stop the pedestrian, a simple warning lamp with a flashing light might be more effective, although we cannot say such a light is intuitive. However, setting warning lamps on all corners is not realistic, simply because they are visually noisy. In other words, the warning lamp conveys a warning to people who do not need to be warned. On the other hand, our system can be regarded as a way of presenting alarms to walking users who need them. We suppose that this design principle is important, and from this perspective, we will consider methods to further increase the efficacy of the alarm.

6. REFERENCES

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