Pedestrian Pace-Maker Light of Affecting Walking Speed

Hiroki Kawada [1]*, Hidehiko Shishido [2,3], and Yoshinari Kameda [2]

[1] *Master's program in Intelligent and Mechanical Interaction Systems, University of Tsukuba, 1-1-1 Tennoudai, Tsukuba, Ibaraki, 305-8573, Japan*
[2] *Center for Computational Sciences, University of Tsukuba, 1-1-1 Tennoudai, Tsukuba, Ibaraki, 305-8573, Japan*
[3] *Currently at Soka University, Japan*

Abstract

We propose a new method of presenting virtual objects of low attention that can affect the walking speed of pedestrians. We call the proposed virtual objects of low attention a Pedestrian Pace-maker Light, hereafter referred to as PPML. The advantages of PPML are that pedestrians can keep clear visibility of the frontal area for safety concerns in situations where PPML is presented in their view through AR glasses. PPML is a set of multiple lighting objects flowing in the direction of travel. Pedestrians perceive a sense of self-motion in the direction of travel through the vection effect caused by the PPML. The experiment was conducted to investigate whether the proposed PPML affects the walking speed of pedestrians or not. We have experimented with the six patterns of PPML. We confirmed that it can affect the walking speed of pedestrians.

Keywords

walking speed, augmented reality, low attention, vection effect, AR glass

1. Introduction

Pedestrian assistance [1,2,3] using augmented reality [4] is the future technology to come. Augmented reality is a technology that augments the real world by adding virtual objects. Among the research on pedestrian assistance using augmented reality, there are some studies on navigation [5,6,7] and notification of surroundings [8,9,10].

Speed is an important factor in walking. If an intelligent and gentle user interface can affect walking speed, a smooth flow of pedestrians would be achieved in our society. If it can let the walking speed down the walking speed, it could improve the safety of pedestrians. Research on pedestrian assistance using augmented reality to affect walking speed and direction has been done [11,12,13]. We have to be aware of the importance of keeping clear visibility of the frontal area for safety concerns in walking. Virtual objects of low attention should be used when presenting virtual objects in an augmented reality intelligent assistance system. Therefore, a new method that affects the walking speed of pedestrians using the presentation of virtual objects of low attention is awaited.

In the case of augmented reality intelligent assistance systems, the effect of virtual objects and the clear visibility of the frontal area of the pedestrian should happen simultaneously. So, the presented virtual objects should not interfere with the visibility of the front area for safety concerns in walking. Note that humans cannot gaze at two objects simultaneously [14]. The virtual objects to be placed in the pedestrian view should attract low attention and keep the clear visibility of the frontal area of pedestrians. Yet the low attention should be sufficient to make influence on their walking.

We propose a new method of presenting virtual objects of low attention that can affect the walking speed of pedestrians. We call the proposed virtual objects of low attention a Pedestrian Pace-maker

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*Corresponding author.
EMAIL: kawada.hiroki@image.iit.tsukuba.ac.jp (H. Kawada); shishido.hidehiko@image.iit.tsukuba.ac.jp (H. Shishido); kameda@ccs.tsukuba.ac.jp (Y. Kameda).
ORCID: 0009-0006-2069-9439 (H. Kawada); 0000-0001-8575-0617 (H. Shishido); 0000-0001-6776-1267 (Y. Kameda).
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Light, hereafter referred to as PPML. The advantage of PPML is that pedestrians can keep clear visibility of the frontal area for safety concerns in situations where PPML is presented in their view through AR glasses. PPML is a set of multiple-lighting objects flowing in the direction of travel. Pedestrians perceive a sense of self-motion in the direction of travel through the vection effect produced by the PPML. The walking speed of pedestrians can be affected by adapting the speed of PPML.

We compose the PPML with a set of multiple tiny cubic virtual objects. The PPML does not interfere with the visibility of the front area of pedestrians. Pedestrians can easily avoid obstacles and check their surroundings even when the PPML is presented.

The experiment was conducted to investigate whether the proposed PPML method affects walking speed or not. We used two shapes and colors of PPML in the experiment; a vertical, green cuboid and a horizontal, white cuboid. In addition, we set three speeds of PPML in the experiment; slow, medium, and fast. We compared the performance of these six types of PPML and presented the results and discussion.

2. Related work

When using augmented reality to present virtual objects, the visibility of the front area of pedestrians should be kept clear, and the virtual objects should not attract too much attention. These two factors are important for pedestrians to walk safely. When presenting virtual objects, there exists an occlusion problem in which virtual objects overlap with the real world [15].

There are studies in which virtual objects affect walking speed and direction, but the visibility of the frontal area for safety concerns was not discussed [11,12,13]. In the study by Yoshikawa et al. [11], a rightward-moving striped vector field was displayed on the floor, and pedestrians walking on it were guided in the right direction. In the study by Lee et al. [12], the walking speed of pedestrians is reduced by placing an avatar that prevents pedestrians from walking in the direction of travel. In the study by Guinet et al. [13], the walking speed of pedestrians is increased and maintained by flowing virtual objects in the direction of travel and making the pedestrians follow them. These studies effectively affect walking speed and direction by presenting virtual objects. However, presenting virtual objects of high attention makes it difficult to keep clear visibility of the frontal area.

There is an approach to reduce the attention to virtual objects. In the study of navigation by Tamura et al. [16], they propose a method called "Active Patterns." This method uses multiple objects flowing in the guiding direction. In their experiment, the gaze information of pedestrians was analyzed, and a questionnaire evaluation of the understandability of the navigation was conducted. As a result, it was found that both navigational clarity and walking safety can be achieved.

Our idea of PPML is inspired by the Pace-maker light for cars. The Pace-maker light has been confirmed to affect the driving speed of cars and can potentially improve traffic flow [17,18,19]. In the study by Igaki et al. [17], simulations were conducted in an environment with Pace-maker light placed on the roadway, and it was confirmed that Pace-maker light contributes to reducing the number of traffic jams. In the study by Yanagihara et al. [18], it is confirmed by simulations that cars actively follow the flow when Pace-maker light is placed on the roadway. In the study by Endo et al. [19], it was confirmed that the Pace-maker light reduces the overall traffic jam by about 20% on an actual highway.

3. PPML

3.1. Deployment

We propose PPML as a new method to both effects the walking speed of pedestrians and keep clear visibility of the frontal area of pedestrians. To manage these two factors, a set of multiple tiny cubic virtual objects flowing in the direction of travel is selected as the PPML. Therefore, pedestrians can keep clear visibility of the frontal area as the virtual objects are too small to occlude the real-world objects in their view. In addition, pedestrians can recognize PPML in their peripheral vision and perceive a sense of self-motion by presenting virtual objects on the side of the frontal area. Figure 1 shows a snapshot of a vertical, green PPML flowing in the direction of travel.

The reasons for this design of the PPML are as follow. The human visual field is divided into two regions; central vision and peripheral vision [20]. The central visual field is used to observe objects and targets directly and is superior in recognizing detailed information. On the other hand, the peripheral visual field is a region that extends outside of the central visual field and is superior in recognizing movements and changes in a wide area. Considering these characteristics, we design the central vision for checking the walking environment of pedestrians. In peripheral vision, the pedestrians can perceive a sense of self-motion in the direction of travel by the PPML because recognizing moving virtual objects in the peripheral vision maximizes the vection effect [21].

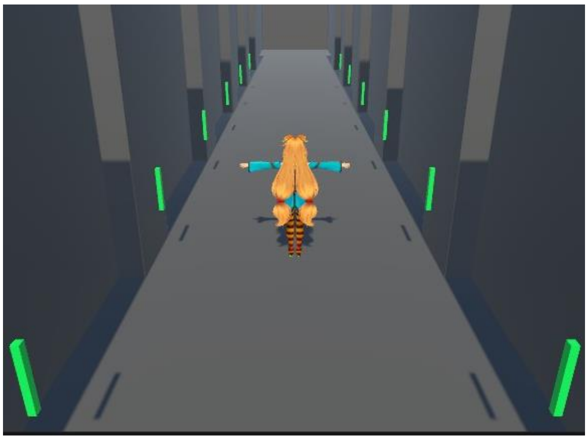

Figure 1: A snapshot of a vertical, green PPML

3.2. Shape and color

As for the shapes of the virtual objects that compose the PPML, pedestrians may pay more attention to the PPML if its shape is complex. Therefore, we adopt a simple shape for the PPML. A study [16] exists that investigated the effects of three simple shapes, a sphere, a cuboid, and a capsule, by flowing them in the direction of travel. This study confirmed no significant difference in the effects of the three. Therefore, the cuboid is adopted as the simple shape in this study.

Two kinds of colors are used for the objects that compose the PPML. One is green, which has a relaxing and reassuring effect on pedestrians [22]. The other is white, which is neutral for ordinary urban scenes. In this study, we created four types of PPML with different shapes and colors, as shown in Figures 2 to 5.

- Horizontal white PPML (Figure 2)
- Vertical green PPML (Figure 3)
- Horizontal green PPML (Figure 4)
- Vertical green PPML (Figure 5)

Figure 2: Horizontal white PPML

Figure 3: Vertical white PPML

Figure 4: Horizontal green PPML

Figure 5: Vertical green PPML

3.3. Speed

We plan to affect the walking speed of pedestrians by adjusting the speed of the PPML. When we plan to slow down the walking speed of pedestrians, we present slower PPML than walking speed. Similarly, if we plan to increase the walking speed of pedestrians, we present faster PPML than walking speed.

The difference from the normal walking speed of pedestrians is important in the selection of the speed of the PPML. Here, three different speeds of PPML are chosen; slow, medium, and fast speed. Because the participants in the experiment were males in their 20s, the medium speed was set based on their average walking speed. The speed values are set as follows.

- Slow speed: 44m/min
- Medium speed: 66m/min
- Fast speed: 100m/min

4. System overview

4.1. Development

We implemented the PPML system to affect the walking speed of pedestrians in the following environment.

- AR glass device: Magic Leap 1
- Unity software: version 2020.3.42f1
- Lumin SDK: 0.25.0
- Lumin OS: 0.98.35

Magic Leap 1[23] is an optical see-through type head-mounted display that can be used while walking. It has a freshening rate of 120 Hz and a viewing angle of 30° vertically and 40° horizontally. The system is developed using Unity [24], and the application program runs in stand-alone mode on Magic Leap 1. Figure 6 shows a snapshot of Magic Leap 1.

Figure 6: Magic leap 1 as AR glass

4.2. Implementation

We initially prepared four types of PPML with different shapes and colors, as shown in Figures 2 to 5. Before the experiment, we conducted a preliminary experiment to select the two types of PPML to avoid a long experiment procedure that may result in unexpected results due to the feeling of getting tired and having an unconscious attitude to the experiment.

In the preliminary experiment, we evaluated the effects of the four PPML types on walking speed by presenting the slow speed PPML. After the experience, we put questionnaires and interviews. The experimental results confirmed that the horizontal, white PPML shown in Figure 2 has the lowest effect of slowing down, and the vertical, green PPML shown in Figure 5 has the highest effect of slowing down. Therefore, we picked up these two for the main experiment.

As for the speed of PPML, we chose the three different speeds described in section 3.3. In addition, the following six PPMLs are selected for the main experiment. Hereafter, the PPMLs are referred to as follows.

- Slow-H-White (SHW): Slow speed, Horizontal and White PPML
- Medium-H-White (MHW): Medium speed, Horizontal and White PPML
- Fast-H-White (FHW): Fast speed, Horizontal and White PPML
- Slow-V-Green (SVG): Slow speed, Vertical, and Green PPML
- Medium-V-Green (MVG): Medium speed, Vertical, and Green PPML
- Fast-V-Green (FVG): Fast speed, Vertical, and Green PPML

5. Experiment

5.1. Procedure

The main experiment was conducted to investigate whether the proposed PPML method affects walking speed or not.

The participants are prepared with adult men to adopt one average speed of walking throughout the experiment [25]. We experimented with 12 male participants in their 20s who were familiar with the presentation of virtual objects using an optical see-through head-mounted display. All the experimental procedures followed our university rule, and it is certified by the ethics review committee.

We explained the PPML to the participants beforehand and demonstrated the proposed method to familiarize them. Then, each participant experienced the six PPMLs in different presentation orders. Each session includes a short walk for around 12 meters followed by a set of questionnaires shown in Table 1. After all questionnaires were completed, we had a certain time of interviews to obtain the subjective opinions of the experimental participants.

The experiment was conducted in the corridor environment shown in Figure 7. We measured the time of a 10-meter walk along the corridor. The difference between the time taken to pass the 2-meter point and the 12-meter point is used to measure the walking time. As a comparison, we also measured the time required to walk 10 meters without the presentation of the PPML. The questionnaire items are shown in Table 1, and the participants rated the three items on a 7-point scale. Note that the actual questionnaire form is written in Japanese, which is the native language of the participants.

Figure 7: Experimental environment

Table 1: Questionnaire items

Q1: How did you feel about the speed of PPML?
1: Very slow 4: Usually 7: Very fast
Q2: Did you see the PPML clearly?
1: I couldn't see it at all. 4: I can't say either way 7: I could see clearly.
Q3: Did you find it difficult to walk with PPML present?
1: I don't feel it at all 4: I can't say either way 7: I felt it very much.

5.2. Results

We calculated the mean and standard deviation of the obtained data and showed them in Figures 8 to 10. The vertical axis of Figure 8 shows the time required for a 10-meter walk, and the vertical axes of Figures 9 and 10 show the 7-level evaluation. The horizontal axis indicates the score without presenting PPML and the ones of the six PPMLs. A one-sided t-test is performed on the data. In the graph, [*] indicates a significant difference of 5%, and [**] indicates a significant difference of 1%.

Figure 8 shows that there is a significant difference of 1% between the fast and medium speeds at the same vertical green PPML. The same happens between the fast and medium speeds at the same horizontal white PPML. In addition, there is a significant difference of 5% between the fast and slow speeds at the same vertical green PPML, and the same between the fast and slow speeds at the same horizontal white PPML. It is confirmed that PPML affects the walking speed of pedestrians. On the other hand, there is no significant difference in the shape and color of PPML.

Figure 9 shows a significant difference of 1% for all the cases of PPML speed. It is confirmed that the slower the PPML speed is, the slower the pedestrian's PPML perceived speed is. As for the shape and color of PPML, a significant difference of 5% is found only between horizontal white PPML and vertical green PPML at the same slow speed. It is confirmed that the perceived speed of PPML in horizontal white PPML may be slower than vertical green PPML.

Figure 10 shows a significant difference of 5% between horizontal white PPML and vertical green PPML in terms of the visibility of PPML. It is confirmed that the visibility of vertical green PPML is higher than horizontal white PPML.

Figure 11 shows that there is no significant difference in evaluating the difficulty in walking by presenting PPML and that they are equally evaluated. In addition, it was confirmed that the PPML gave pedestrians no difficulty in walking.

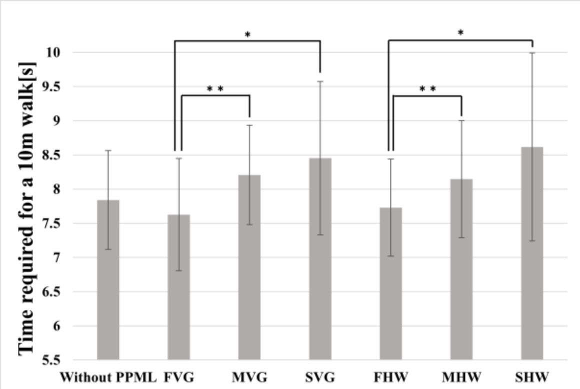

Figure 8: Measured time required for a 10-meter walk

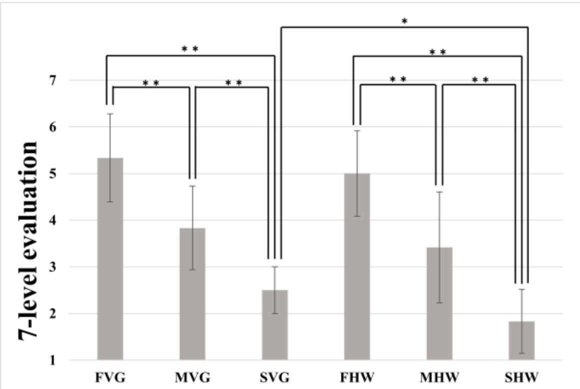

Figure 9: Result of questionnaire evaluation of pedestrian's PPML perceived speed

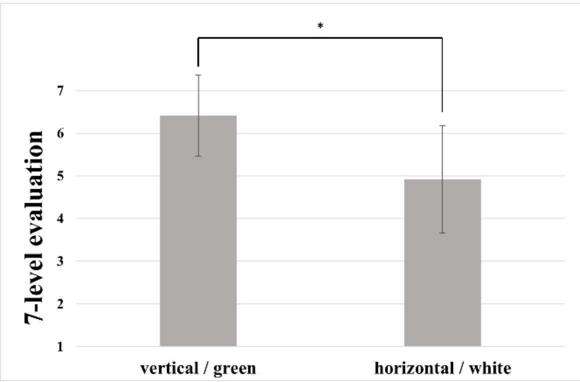

Figure 10: Result of questionnaire evaluation of PPML visibility

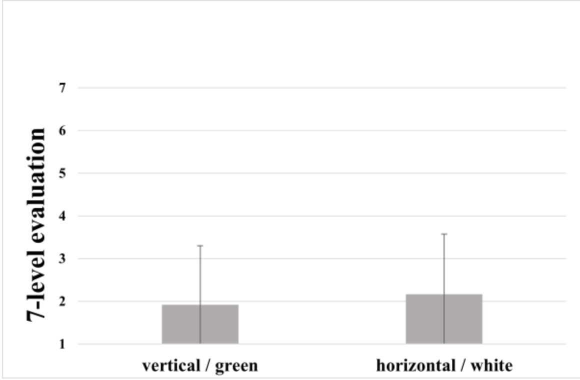

Figure 11: Result of questionnaire evaluation of difficulty of walking when presenting PPML

5.3. Discussion

From Figure 8, it is confirmed that PPML affects the walking speed of pedestrians. In addition, it is confirmed that there was no significant difference in the effect on the walking speed between horizontal white PPML and vertical green PPML. On the other hand, in the interviews, some participants said that vertical green PPML had a more substantial effect on the walking speed of pedestrians than horizontal white PPML. Therefore, further experimentation would be needed to investigate how the PPML can affect walking speed regardless of its shape and color.

From Figure 9, it is confirmed that the slower the PPML speed is, the slower the pedestrian's PPML perceived speed is. In addition, it is confirmed that the perceived speed of PPML in horizontal white PPML may be slower than vertical green PPML. In the interviews, some participants said that some participants perceived vertical green PPML to be faster than horizontal white PPML. Therefore, there were no discrepancies between the interviews and the experimental results.

From Figure 10, it is confirmed that the visibility of vertical green PPML is higher than horizontal white PPML. In the interviews, some participants said that horizontal white PPML is more challenging to see and less present than vertical green PPML. Therefore, there were no discrepancies between the interviews and the experimental results.

From Figure 11, it is confirmed that participants evaluated the perceived walking difficulty equally when presented with vertical green PPML and horizontal white PPML. In the interviews, some of the participants said that they did not feel any difficulty walking with both PPMLs. Therefore, it is indicated that the proposed method may be less likely to give pedestrians a sense of difficulty in walking.

6. Conclusion

We proposed the PPML as a new method of presenting virtual objects of low attention. This method can both affect the walking speed of pedestrians and keep the clear visibility of the frontal area of pedestrians.

The experiment was conducted to investigate whether the proposed PPML method affects walking speed or not. From the experimental results, it is confirmed that PPML affects the walking speed of pedestrians. In addition, there is no significant difference in the effect on the walking speed of pedestrians between horizontal white PPML and vertical green PPML. It is also confirmed that the proposed method is less likely to cause difficulty in walking.

We think more investigation of the effect of walking speed change by PPML should be conducted. The test of clear visibility for safety concerns should be done to very our proposed approach is effective in practical situations too.

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