Effect of Presentation Position on the Visibility of Dynamic Signs

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ABSTRACT

Dynamic signs provide warning and guidance information by using images that change visual properties (luminance, size, location, etc.) depending on their situation. In this paper, we study the effect that the presentation position of dynamic signs has on their visibility among three age groups.

1 Introduction

Dynamic signs are a type of information presentation system that uses images whose position or luminance can be changed to convey guidance or warnings to the public. They also enable the content conveyed to vary in response to the environment or to the circumstances of the viewer [1].

We are accumulating data based on ergonomic experiments so that we may contribute to the development of international standards for the visibility, safety, and accessibility of dynamic signs [2, 3, 4].

We previously investigated the effects of various animation type (e.g., flashing and moving), presentation duration [2], and repetition frequency [1] on the reading of sign content in terms of the effect of age. In this paper, we report the results of an investigation into the reading accuracy of signs during the execution of a dual task at multiple presentation positions (i.e., on the floor, front wall, and ceiling).

2 Methods

2.1 Participants

To clarify the effect of age and cognitive function on sign reading, we performed experiments involving 90 men and women in their twenties (mean age 23.2, standard deviation [SD] 2.11, N = 30), forties (mean 45.3, SD 2.909, N=30), or sixties (mean age 62.3, SD 1.55, N = 30). All participants had normal vision, hearing, and walking ability, and all received compensation for their participation. On the day of the experiment, we verified that the participants were fit to participate by asking them to complete a questionnaire concerning their physical condition on that day, and by measuring their monocular and binocular vision using a Landolt ring test from 5 m away and performing a Stereo Fly Test (Stereo Optical Co. Inc., Chicago, IL). We also administered the Mini-Mental State Examination to evaluate cognitive function.

No test participants had prior knowledge of the test contents. The experimental protocol was approved by the Ergonomics Committee of the National Institute of Advanced Industrial Science and Technology (AIST). All participants provided written informed consent before participating in the experiment.

2.2 Apparatus

Computer graphic images were projected from 4,000-lumen projectors (NP-M402XJD; NEC, Tokyo, Japan) onto four square screens measuring 3 m^2 placed to the left and right of the viewer, as well as to the front and on the floor, using the CAVE immersive virtual reality device developed by the University of Illinois. Participants viewed these projections through glasses polarized using the circular light polarization method. We used the Vicon system (Vicon Motion Systems Ltd., Oxford, UK) to perform contactless measurements of each participant's head position at a sampling rate of 120 Hz. The head position data were then transmitted to the CAVE system via an Ethernet connection where it was used to correct rendering distortions [2].

2.3 Stimuli

We performed the experiment in a virtual-reality environment simulating an underground shopping center with a T-junction [2]. The passageway splits into left and right branches at the T-junction, with three destinations (1st, 2nd, and 3rd doors) along each branch. The passageway width was 5 m, and there was a series of shops over a 30-m range on both sides of the junction. All participants started at a point 15 m from the junction at coordinates (x,y) = (0.0,−15.0). The display position of the dynamic sign was set so that the sign's center was located at one of three coordinates: (1) on the floor, located at coordinates (0.0, 1.8, 0.0); (2) on the front wall, located at coordinates (0.0, 2.5, 1.5); or (3) on the ceiling, located at coordinates (0.0, 1.8, 2.9). The sign was approximately 2 m wide and 1.15 m tall.

The three destinations were depicted with circle, triangle, and star symbols, and the sign's center had dimensions of 0.36 × 0.36 m (Fig. 1) [2]. In each test, participants were asked to read the position and direction of the star from the dynamic sign. A sliding arrow was added to the left or right of each symbol, with the distance from the junction implied by either the position of the arrows or the distance that the arrows slid. The arrows indicating the three destinations all moved 0.18 m per second, but the average positions of the arrows varied, with the distance between average positions and marks (0.49 m, 0.67 m, and 0.85 m) implying the positions of the destinations.

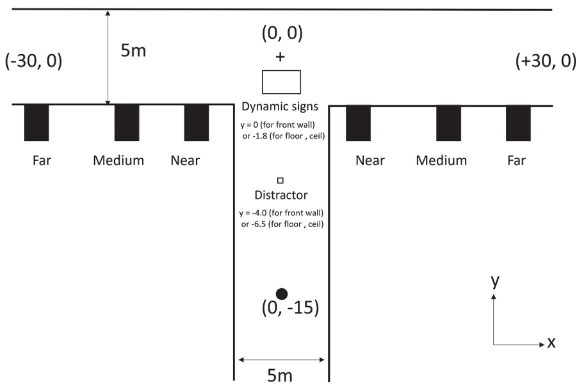

Fig. 1 Layout of the underground passageway used in the experiment [2].

To examine the effect of order arrangement of symbols on the visibility, four combinations of direction and distance information were prepared (Fig.2).

Directions in sequence and positions in sequence (DI–PI): In this alignment, the direction arrows for all symbols were on either the right or the left. The travel distance indicators (shown by the arrow positions) were all in order (either "1st–2nd–3rd" or "3rd–2nd–1st"; Fig. 2a).

Directions in sequence and positions in disorder (DI–PD): In this alignment, the direction arrows for all symbols were on either the right or the left. However, the travel distance indicators were not in a fixed order (Fig. 2b).

Directions in disorder and positions in sequence (DD–PI): In this alignment, some direction arrows were on the right and others were on the left. However, the travel distance indicators were all in order (either "1st–2nd–3rd" or "3rd–2nd–1st"; Fig. 2c).

Directions in disorder and positions in disorder (DD–PD): In this alignment, some direction arrows were on the right and others were on the left. However, the travel distance indicators were not in a fixed order (Fig. 2d). Multiple signs were created to fulfill each of these conditions, with the circle, triangle, and star positions randomized in each case when assigned to each participant.

In this experiment, the appearance of the dynamic sign was preceded by the presentation of another visual stimulus (distractors). During the experiment, squares, pentagons, diamonds, and blanks were presented in random succession on the floor, and participants were asked to press a button on a controller only when a square sign appeared. The presentation time for each shape was 1/6 s. These stimuli were 0.25 m wide with a height of 0.25 m. The center was located at the coordinates (0.0,-6.5,0.0) when the dynamic sign was presented on the floor or ceiling, and (0.0,-4.0,0.0) when it was presented on the front wall. This was done to minimize the distance between the two.

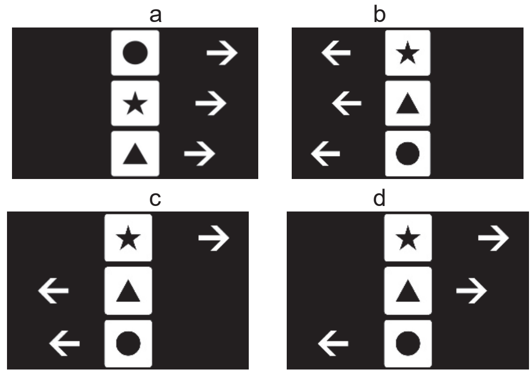

Fig. 2 Examples of four alignment combinations.

2.4 Procedure

During the experiment, participants wore a virtual-reality headset while standing in the center of the floor. The starting point in each trial was the base of the T-shaped passageway with coordinates (x,y) = (0.0,−15.0), and participants automatically moved forward from that point at a speed of 4 km/h. The display position of the dynamic sign was either on the floor, the ceiling, or the front wall. The presentation times for sliding and blinking were always 4 s, so the sign presentation started when the participant was approximately 4.4 m from the sign center.

The participants' task was two-fold. First, they observed a series of squares, pentagons, and diamonds projected on the floor before the dynamic sign was presented. They then pressed a button on a controller only when a square was shown. If a participant noticed a dynamic sign in their field of view, then they would focus their attention on it. They were then asked to ascertain the target destination positions as quickly as possible while the sign was displayed, and to verbally report the direction and distance. The experimenter used left and right buttons on a wireless device to record what they reported. This dual task is useful for revealing the spatial characteristics of divided attention [5].

Each participant viewed 48 trials under all display conditions: for each of the four alignment conditions (DI–PI, DI–PD, DD–PI, and DD–PD), four types of signs were created with the circle, triangle, and star symbols in random positions, and each of these signs was viewed at three different presentation times for a total of 4 × 4 × 3 = 48 trials.

3 Results

For the participants of each age group, four types of signs were created for a single alignment combination, and five types of correct responses (0%, 25%, 50%, 75%, and 100%) were obtained as a result of reading each one. This was obtained for four different alignment combinations and three different presentation position combinations, and was used as the sign-reading performance of each subject. The combinations of presentation position and placement conditions, as well as the ratio of correct responses, are shown in Table 1, and the results of the analysis of variance are described.

In the results for participants in their twenties, all conditions had significant effects (presentation position $F(2,52) = 59.60$, $p < .01$; direction $F(1,26) = 36.55$, $p < .01$; distance $F(1,26) = 9.00$, $p < .01$). A significant interaction between presentation position and direction was also observed ($F(2,52) = 6.04$, $p < .01$), which prompted 'a Bonferroni test. The results showed that the correct ratio was significantly lower for the floor and ceiling displays than for the frontal display in both the DI and DD conditions.

For participants in their forties and sixties, the presentation position and the neatness of the distance information had significant effects, while the neatness of direction had no significant effect (sixties: presentation position $F(2,52) = 146.41$, $p < .01$; direction $F(1,29) = 16.99$, $p < .01$.; distance $F(1,29) = 20.96$, $p < .01$; forties: presentation position $F(2,58) = 200.64$, $p < .01$; direction $F(1,29) = 5.56$, $p < .05$; distance $F(1,29) = 25.88$, $p < .01$). For presentation position, the results of the 'Bonferroni test indicated that for both age groups, the correct ratio was significantly lower when the dynamic sign was presented on the floor and ceiling than when it was presented in the front. Since there was a significant interaction between the presentation position and the distance condition (sixties: $F(2,58) = 6.21$, $p < .01$; forties: $F(2,58) = 13.20$, $p < .01$), a 'Bonferroni test was conducted for this as well. The results showed that the ratio of correct responses was significantly lower for the floor and ceiling displays than for the frontal presentation in both of the PI and PD cases.

Table 1. Summary of results

Twenties

Position	DI / DD	PI / PD	Correct Ratio	SE
Front	DI	PI	0.89	0.22
Front	DI	PD	0.81	0.29
Front	DD	PI	0.69	0.30
Front	DD	PD	0.44	0.35
Floor	DI	PI	0.43	0.40
Floor	DI	PD	0.36	0.31
Floor	DD	PI	0.31	0.34
Floor	DD	PD	0.27	0.26
Ceiling	DI	PI	0.32	0.37
Ceiling	DI	PD	0.22	0.29
Ceiling	DD	PI	0.25	0.31
Ceiling	DD	PD	0.19	0.23

Forties

Position	DI / DD	PI / PD	Correct Ratio	SE
Front	DI	PI	0.89	0.18
Front	DI	PD	0.69	0.33
Front	DD	PI	0.87	0.22
Front	DD	PD	0.53	0.33
Floor	DI	PI	0.21	0.30
Floor	DI	PD	0.16	0.22
Floor	DD	PI	0.09	0.19
Floor	DD	PD	0.14	0.22
Ceiling	DI	PI	0.18	0.28
Ceiling	DI	PD	0.04	0.11
Ceiling	DD	PI	0.10	0.20
Ceiling	DD	PD	0.09	0.17

Sixties

Position	DI / DD	PI / PD	Correct Ratio	SE
Front	DI	PI	0.87	0.25
Front	DI	PD	0.60	0.32
Front	DD	PI	0.66	0.34
Front	DD	PD	0.46	0.30
Floor	DI	PI	0.24	0.26
Floor	DI	PD	0.16	0.21
Floor	DD	PI	0.14	0.29
Floor	DD	PD	0.12	0.20
Ceiling	DI	PI	0.13	0.24
Ceiling	DI	PD	0.06	0.12
Ceiling	DD	PI	0.10	0.21
Ceiling	DD	PD	0.04	0.14

4 Discussion

Compared with subjects in their twenties, the other age groups exhibited a clear decrease in the percentage of positive responses over time. On the other hand, the rate of correct responses for the frontal view was stable across all age groups. For example, when both direction and distance were in the correct order, the rates of correct responses for subjects in their twenties, forties, and sixties were 89%, 89%, and 87%, respectively. In the case where the direction and distance disorder was considered difficult, the rates of correct responses for participants in their twenties, forties, and sixties or older were 44%, 53%, and 46%, respectively. Similarly, a broad trend suggests that for floor surfaces, the results for participants in their forties were rather close to those for participants in their sixties, and conversely, for ceilings, the results for participants in their forties were close to those for participants in their twenties. This asymmetry in change over time is interesting in its own right.

These results suggest that the optimal location for dynamic signs is in front of buildings, as this will allow them to be noticed by a wider range of age groups without being obscured by disturbances. On the other hand, presenting them on the floor or ceiling should only be done after carefully considering the characteristics of the signs' target audience. Finally, we note that, despite the relatively high rate of correct responses among all age groups, presenting dynamic signs in front of buildings may not account for dispersion of attention by other distractions, such as the use of phones while walking. We believe that raising awareness of manners and to pay attention to activities that could impede human flow or cause accidents is an issue that needs to be addressed separately from ergonomic characteristics.

5 Conclusion

The relationship between dynamic sign placement and visibility was examined for experimental participants in three age groups using a dual task. The results showed that when the sign was presented in the front, the correct response rate was relatively high regardless of age. On the other hand, when the signs were placed on the floor or ceiling, the detection was very inaccurate regardless of the age of the participants.

These results suggest that it is important to consider the location of signs in order to communicate them to people with diverse perceptual abilities and cognitive attributes who use public spaces.

6 Acknowledgement

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