Effect of distance between a displayed object and a frame on depth perception in observing stereoscopic display

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Abstract

I studied on the effect of a stereoscopic display's frame in depth perception. There were three patterns of the relationship between an object on a stereoscopic display and its frame. The first case is that an object displayed on a stereoscopic display was fixed and the display varies in size (Fig. 1). The second case was that a stereoscopic display's frame is fixed and an object's on it is varies in size (Fig. 2). The third case was that an object's and a stereoscopic display's size was fixed and a displayed object varies in size (Fig. 3). I conducted three experiments to examine whether the depth perception is changed in viewing the objects on the stereoscopic display in above three cases. The first result was that the perceived distance between an object and a background was longer in viewing the small display than the large display. The second result was that the perceived distance between an object and a background was longer in viewing the small object than the large object. The third result was that the perceived distance between an object and a background is longer in viewing the object displayed on the side of the display than on the center. These results suggested that we could get clear depth perception in viewing a small stereoscopic display like a mobile phone's display.

Keywords-component; stereoscopic display; depth perception; frame

1. Introduction

The history of stereoscopic display is as old as photography. So far, stereoscopic display was tried in various fields like as photography, movie, TV, robotic surgery [1], game and a smartphone. Stereoscopic display has been mainly used in a movie theater as yet. On the other hand, a small stereoscopic display like a smartphone has gone out of use. It is thought that the cause is that the stereoscopic effect is disturbed in viewing a small stereoscopic display because of its size. The distance between a virtual object displayed on a large stereoscopic display and its real frame varies. On the other hand, the distance of a small stereoscopic display is always short. It is likely that the difference of the distance cause stereoscopic effect's variation. Why the distance makes the stereoscopic effect vary. The possibility reason is that cognition of a frame being in real space distorts a displayed object's perceived distance in virtual space. So, I investigated the depth perception in the case of varying the distance between an object displayed on a stereoscopic monitor and a monitor frame.

Fig.1
When a frame varies in size and a displayed object does not vary in size and position, distance between the frame and the object varies.

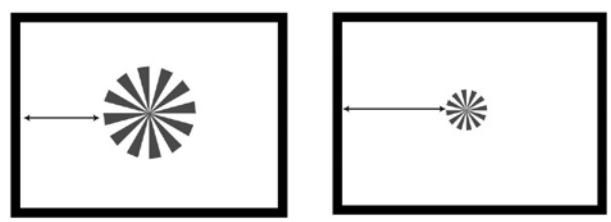

Fig. 2
When a displayed object varies in size and an object and a frame does not vary in size and position, distance between the frame and the object varies.

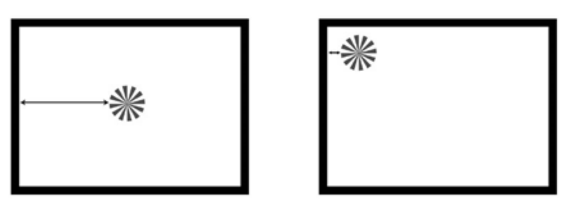

Fig. 3
A displayed object varies in position. An object and a frame does not vary in size.In such case, distance between the frame and the object varies.

There are three cases that I can think of the variation of the distance between a frame and a displayed object (Fig. 1, Fig. 2 and Fig. 3). Firstly, when a displayed object's size is constant and frame size varies, the distance between a displayed object and a frame varies. Secondly, there is a case that different size objects displayed on the same stereoscopic monitor. Finally, there is a case that position where an object is put varies. I conducted three experiments to examine whether the depth perception is changed in viewing the objects on the stereoscopic display in above three cases.

II. Experiment 1

In the experint 1, I investigated if the variety of the dsitance between a frame and a displayed object by monitor size's variety caused to vary subjects' distance perception.

Method

Subjects viewed the stereoscopic monitor (21.5 inch LCD, ZALMAN ZM-M215W). I fit a paper frame into the original monitor frame to vary monitor size (Fig.4, Fig. 5 and Fig. 6). I set three display size conditions (large: 421mm×236mm, middle: 177mm×100mm and small: 78mm×44mm). The large monitor size corresponded to 20-inch monitor, the middle monitor size corresponded to 8-inch monitor and the small size monitor corresponded to 4-inch monitor. Fig. 7 showed the visual target on the stereoscopic display. Its size was 36mm across in diameter. Table1 showed distance between the target and the frame each display size. Subjects viewed targets on the stereoscopic display by crossing method. The magnitude of disparity was 0.11 degrees. So subjects could observe that the target pop out from the monitor (Fig.8). A check pattern positioned behind the target as background and the magnitude of it's disparity was 0 degree. The square's side length of check pattern was 25mm. At first, the target was displayed on the stereoscopic display whose size was one of three sizes (large middle and small). Successively, the target was displayed on it whose size was another size. Monitor size was varied by manually replacing a frame. Subjects compared two targets and orally reported which target was more pop-up. Pairs of monitor size were produced six types (large-middle, large-small, middle-large, middle-small, small-large and small-middle). When it was difficult for subjects to judge, monitor size could be change by the experimenter. Fifteen university students participated in the experiment. All subjects could see a stereoscopic image normally. Observing distance was 50cm.

Fig. 4
Large condition's display

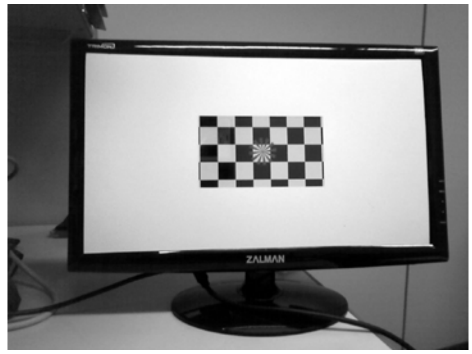

Fig. 5
Middle condition's display

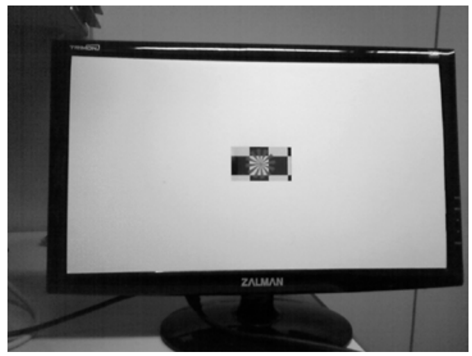

Fig. 6
Small condition's display

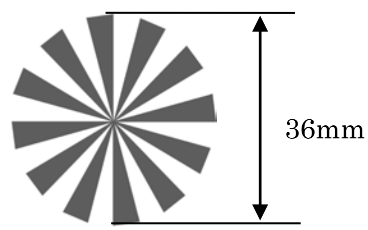

Fig. 7
Target used in the experiment 1

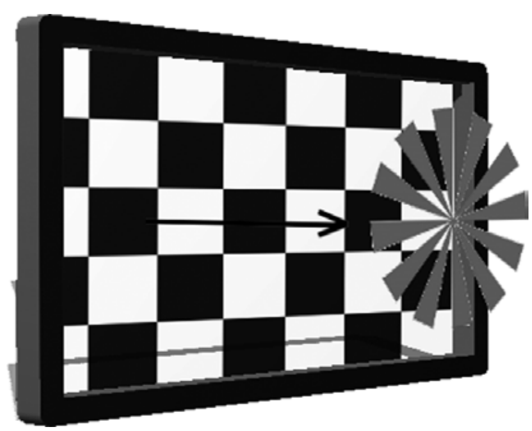

Fig. 8
Figure showed subject's view. The target popped out from the

stereoscopic monitor.

TABLE 1
DISTANCE BETWEEN A FRAME AND A TARGET OF EACH DISPLAY SIZE

Dispay size	Distance between monitor' s left edge to the target (mm)	Distance between monitor' s top edge to the target (mm)
Large	193	100
Middle	71	32
Small	21	4

Results

I counted the number of selections each monitor sizes. Fig.9 showed the number of selections each monitor sizes. It showed that subjects perceived more pop out the target on middle and small monitor than large size (p<. 01). The result suggested that the perceived distance between an object and a background should be longer in viewing the small display than the large display. These things did not indicate that the target being away from the frame should be more pop out than it close to the frame.

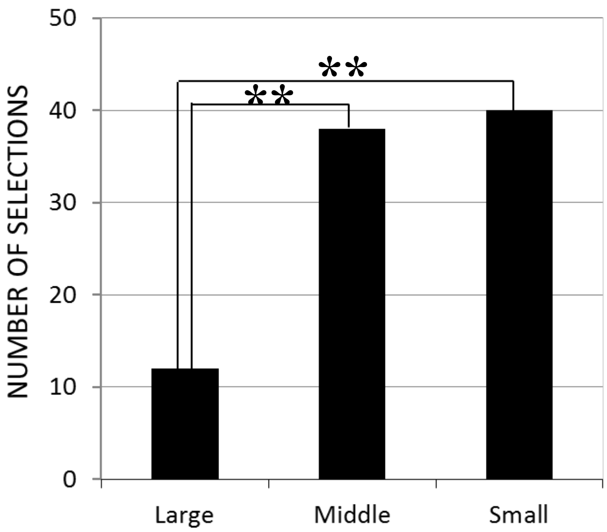

Fig.9
X-axis and Y-axis showed observing condition and the choosing numbers each monitor size respectively

III. Experiment 2

In the experiment 2, I investigated if the variety of the distance between a frame and a displayed object by a target size's variety caused to vary subjects' distance perception.

Method

Experimental environment was almost same as the experiment 1. But subjects viewed target over the display's original frame, because I did not use paper frames that were used in experiment 1. The monitor size was 477mm×268mm. There were three target's size (large: 216mm in diameter, middle: 108mm in diameter and small: 36mm in diameter) (Fig. 10, Fig. 11 and Fig. 12). Table 2 showed the distance between the left edge of the target on the monitor for left eye and the display frame. The magnitude of target's and background's disparity was 0.11 degrees and 0 degree respectively (crossing method) as well as the experiment 1.

Firstly, a target displayed on the stereoscopic monitor. Secondly other size target displayed. Subjects task was to judge which target being more separate from the monitor and they reported it orally.There were six combinations of target size. Pairs of monitor size were produced three types (large-middle, large-small and middle-small). Subjects freely switched a target by pushing the keyboard. Fifteen subjects who participated in the experimented 1 participated in the experiment 2.

TABEL 2
DISTANCE BETWEEN A FRAME AND A TARGET OF EACH TARGET SIZE

Target size	Distance between monitor' s left edge to the target (mm)	Distance between monitor' s top edge to the target (mm)
Large	131	26
Middle	185	80
Small	221	116

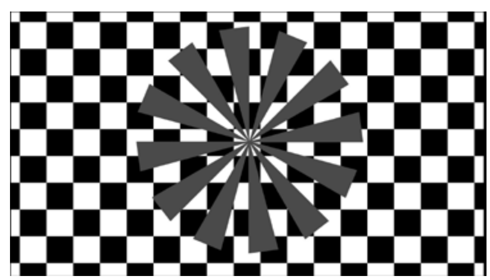

Fig. 10
Large condition's target

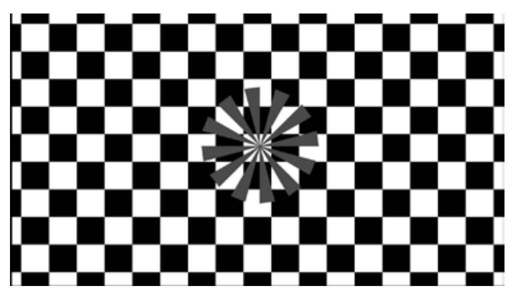

Fig.11
Middle condition's target

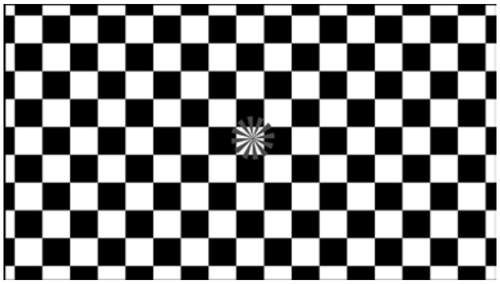

Fig. 12
Small condition's target

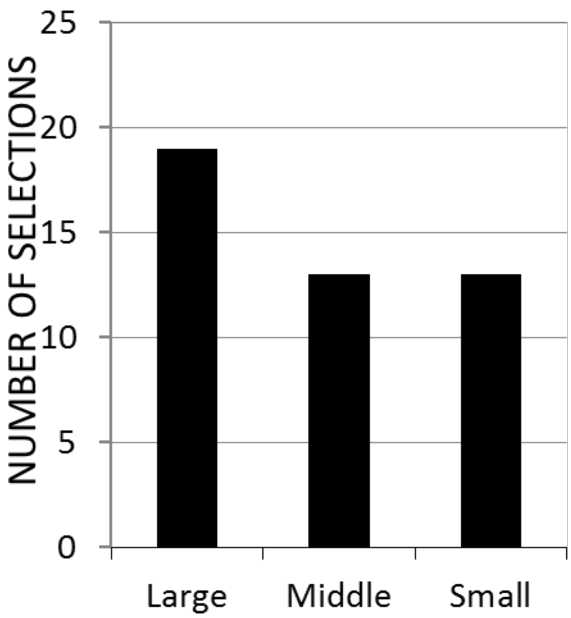

Fig. 13
X-axis and Y-axis showed observing condition and number of selections respectively

Results

I counted the number of times that subjects choose every target sizes. Fig.13 showed the number of selections each target's sizes. Total number of large condition was more than other conditions. There was no significant difference between target sizes. The result did not show that the perceived distance between an object and a background was longer in viewing the small object than the large object. These things did not indicate that the target being away from the frame should be more pop out than it close to the frame.

IV. Experiment3

In the experiment 3, I investigated if the variety of the distance between a frame and a displayed object by target position's variety caused to vary subjects' distance perception. I produced the condition that a target placed on the center of the stereoscopic monitor and the condition that it placed on the surround. And I compared the depth perception in observing both condition's target.

Method

The experimental instrument and environment were the same as the experiment 2. The target was the same as it used in the experiment 1. Checker pattern used in the experiment 1, 2 was used as background too. Target's disparity was 0.11 degrees (cross method) and background's disparity was 0 degree. One position was the center of the stereoscopic monitor and others were the surrounds. Table 3 showed targets' positions. Targets' position had seven places around the stereoscopic monitor and the center of it. I compared depth perception of No. 4 position with other poison (No.1, No.2, No.3, No.5, No.6 and No.7) (Fig. 14). Therefore, I produced six pairs of target positions (No.1-No.4, No.2-No.4, No.3-No.4, No.5-No.4, No.6-No.4 and No.7-No.4). Subjects freely switched target position by pushing the keyboard. The trial order was No.1-No.4, No.2-No.4, No.3-No.4, No.5-No.4, No.6-No.4 and No.7-No.4. Subjects were the same as the experiment 1 and 2.

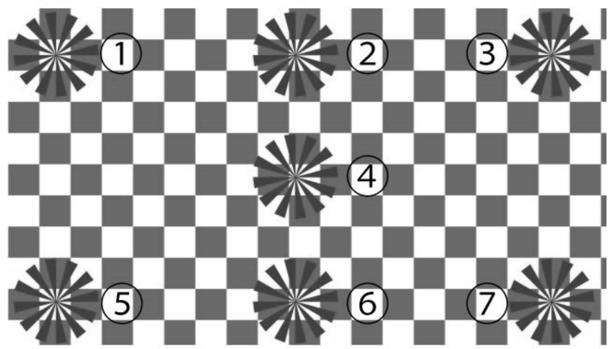

Fig. 14
Target position in each position No.

Results

I counted the number of times that subjects selected No.4, which was placed the center, and the total number of times of others, which were placed surroundings (No.1, No.2, No.3, No.5, No.6 and No.7). Fig.15 showed results. The results showed that subjects perceived targets displayed around the stereoscopic monitor more pop out than the center ($p < .01$).

The perceived distance between an object and a background was longer in viewing the object displayed on the side of the display than on the center. These things did not indicate that the target positioned at the center should be more pop out than it positioned near frame. On the contorary, the target near frame was subjectively more pop out than it at the center.

TABEL 3
DISTANCE BETWEEN A FRAME AND A TARGET OF EACH TARGET POSITION NO.

Target position No.	Distance between monitor edge and the target (mm)	Distance between monitor edge and the target (mm)
1	7	7
2	221	7
3	7	7
4	221	116
5	7	7
6	221	7
7	7	7

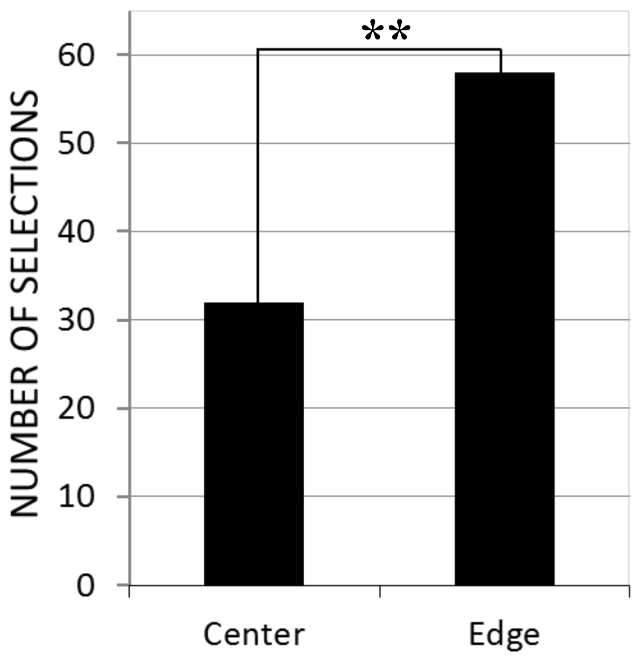

Fig. 15
X-axis and Y-axis showed observing condition and number of selections respectively

V. General Discussion

In the experiment 1, I investigated if the variety of the distance between a frame and a displayed object by monitor size's variety caused to vary subjects' distance perception. The result showed that the perceived distance between an object and a background was longer in viewing the small display than the large display. In the experiment 2, I investigated if the variety of the distance between a frame and a displayed object by a target size's variety caused to vary subjects' distance perception. The result did not showed that the perceived distance between an object and a background was longer in viewing the small object than the large object. In the experiment 3, I investigated if the variety of the distance between a frame and a displayed object by target position's variety caused to vary subjects' distance perception. The results showed that subjects perceived targets displayed around the stereoscopic monitor more pop out than the center.

Results of the experiments 1,2, and 3 did not show that stereoscopic monitor' s frame reduce stereoscopic effect, although it was generally said that it reduced stereoscopic effect. On the contrary results of the experiment 1 and 3 showed that it accelerated stereoscopic effect.

Frame's cognitive factor might increase depth perception in observing a target displayed on the small frame size stereoscopic monitor. In the experiment 1, many subjects reported that they felt observing through an observation window and the background existing over the window, when observing the target on the stereoscopic monitor having the small frame. As subjects perceived that the background displayed on the small frame stereoscopic monitor existed further than it displayed on large, subjects perceived the distance between the target and the background being more separate in observing the target on the small frame stereoscopic monitor. In the experiment 3, subjects reported that they felt looking up at or looking down at the target in observing the target displayed on the edge. This result indicated that subjects' depth perception increased in observing a target displayed on edge on account that they became conscious that the space between a target and a frame was large.

People use disparity as important depth cue in observing a stereoscopic display. At that time, cognitive factor like cognition about a frame can influence depth perception of stereoscopic image. Results of this study indicated that a frame of the stereoscopic display and a small size stereoscopic display could serve to further promote depth perception. And those results indicated that even small stereoscopic monitors like smart phones could offer sufficient stereoscopic effect.

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V. Conclusion

I studied on the effect of a stereoscopic display's frame in depth perception.Results of the experiments did not show that stereoscopic monitor' s frame reduce stereoscopic effect, although it was generally said that it reduced stereoscopic effect. On the contrary results of the experiment 1 and 3 showed that it accelerated stereoscopic effect.These results suggested that we could get clear depth perception in viewing a small stereoscopic display like a mobile phone's display.

References

[1]I. Uyama, K. Suda, F. Yoshimura, K. Taniguchi and S. Sato, " The present and prospects for robotic surgery in gastrointestinal surgeries", J.Jpn. Surg. Soc., vol. 113, No. 4, pp. 384-387, 2012