Effective Usage of Stereoscopic Visualization for the Learning of a Motional Mechanism

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Abstract. 3D stereoscopic display is expected to be an advantageous interface of the learning materials to facilitate viewer's spatial recognition. To reduce the visual fatigue in viewing rotational motions, and to make use of the effect of stereoscopic display, an intermittent exposure method was considered and compared with continuous exposure method. Further, the effect of one-second exposure supplemented with the projected rotational motion was examined. It was suggested that even such a short-time exposure was effective for improving spatial recognition, reducing the visual fatigue remarkably.

Keywords: 3D stereoscopic display, rotational motion, spatial perception.

1 Introduction

Stereoscopic 3D (S3D) display is one of a popular technological trend for the interface of the machines such as Nintendo 3DS[1]. S3D graphics is also advantageous for educational purposes on account of following reasons: (1) depth recognition stabilizes the perception of the 3D structure; (2) the 3D image of the moving object is easily recognizable; and (3) real-time manipulation of the virtual camera enhances intuitive exploration [2].

However, visual discomfort and fatigue from viewing the stereoscopic presentation has become an issue for the introduction of 3D stereoscopic materials into classrooms [3]. Therefore, an appropriate instruction method must be developed in order to effectively use such stereoscopic displays.

Many students have difficulties in understanding physical phenomena that is occurring on the moving objects. Commonly, it is more difficult to understand when the motion of substance in question changes on the moving object [4]. Typical example of this is the commutator, the slip rings, of a simple DC motor. For an easy-to-understand presentation, the stereoscopic visualization is expected effective.

In this study, we compare the effects of two scenarios of showing S3D materials in the learning of DC motor, i.e., continuous and intermittent exposure of S3D, on the understanding of the role of commutator and the onset of visual fatigue. Then, in order to clarify the effect of short time exposure of S3D on the recognition of a three dimensional structure, we carry out a simple test on the three dimensional perception

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induced by a rotational motion projected onto a 2D plane, and by the addition of short time and continuous exposure of S3D images.

2 Method

2.1 A DC Motor Model

A model of a DC electric motor, created by using Adobe Flash CS5 with Papervision3D library, rendered a side-by-side S3D image with a resolution of 1000 × 600 pixels for each viewport, and a maximum of six types of vectors were exhibited in the model space. The vectors exhibiting electric current and magnetic force were drawn on the wire in rotational motion. In addition, the moving elements along the wires and a commutator expressed the flow of electrons (Fig. 1).

In order to display the motor model, a dual projector with linear polarization (portable 3D projector 3DP-TX04, T&TS CO., Ltd.) was used to project superimposed side-by-side images (1024 × 768 pixels) onto an 80-inch polarization-preserving screen. The students viewed the images through polarized glasses, and they were asked to move to appropriate positions in front of the screen.

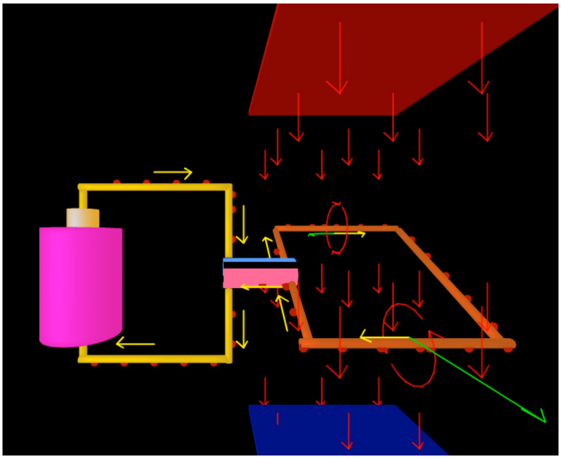


Fig. 1. A view of the 3D motor model with vectors of physical quantities. A commutator, colored pink and sky blue, is shown at the center with the yellow current vectors and small red discs exhibiting the electrons.

2.2 Classroom Demonstration

Lectures using a S3D model were conducted in three different classes in the Faculty of Education at Tokyo Gakugei University. For the first two classes, majorly consisted of second-year students, the stereoscopic images were continuously exposed to the students during the lectures. This type of exposure to the students is hereafter referred to as “continuous exposure.”

For the third class, which consisted of 30 third-year students, S3D images were shown during the explanation of the first scene and just before the transition to the following scene. This type of exposure is hereafter referred to as “intermittent exposure.”

All three classes began with a demonstration of an experiment based on Fleming’s left-hand rule. After a demonstration of the experiment, motor model viewings were conducted in the following manner. First, the entire motor model was shown in non-stereoscopic display. After an explanation of the model, S3D viewing was commenced from the entire view, then, close-up views of rotating wire from multiple points, and it ended with the close-up and explanation of the commutator. Finally, a questionnaire regarding experiences of visual fatigue was presented to the students.

2.3 A Perception Test on Rotating Lines

Two lines with randomly chosen lengths and directions were generated inside a fixed cubic frame, and were rotated along an axis that was set at a randomly chosen position inside the cube space (Fig. 2). The angle of rotation was chosen at random, while the direction of rotation was fixed. The rotating motion was animated, and the duration time of rotation was approximately three seconds at longest. For presentation, the generated lines, which were shown fixed for one second (“rest phase”), were rotated (“rotation phase”), and were again fixed to let the examinee choose a line of which center position was seen closer the examinee. The following three types of display were tested. 1) Non-stereoscopic display, in which only the projected rotation images played a role of pictorial clues for 3D recognition. 2) Pre-exposure of S3D images for one second, in which the lines and cubic frame were shown in S3D in the rest phase. After the rest phase, the images and animation were shown in non-stereoscopic display. 3) Continuous exposure of S3D, in which images were shown in S3D from the beginning to the end. The examinee sat at approximately 2m from the screen and viewed the images. They chose lines by the mouse-over on line. Each examinee carried out choosing more than 100 times successively for each display type.

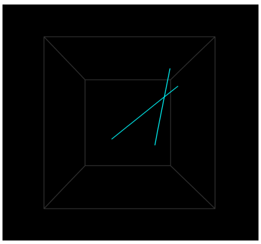


Fig. 2. A view of the rotating lines test. Gray lines of fixed cube show 1000 arbitrary unit length. Two lines in sky blue show test lines and are rotated along a randomly chosen axis.

3 Results and Discussion

3.1 A Comparison between Continuous and Intermittent Exposure Method

Figure 3 shows the results of students' responses in regard to the effectiveness of non-stereoscopic 3D display (white bars) and to the improvement of effectiveness in S3D (gray bars). Students were asked whether the non-stereoscopic 3D image was effective to figure out the structure and mechanisms of the elements of the motor. 74% of students agreed or strongly agreed with the statement. Then, students were asked whether the S3D display improves their recognition of structures. 87% of students agreed or strongly agreed the improvement of effectiveness on understanding the structure by changing the display from non-stereoscopic to stereoscopic.

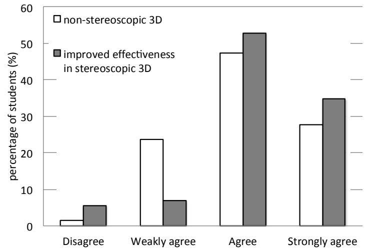


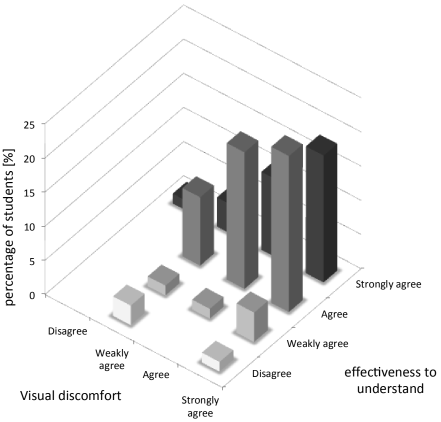
Fig. 3. Results of questionnaire on the effectiveness of 3D and S3D display on understanding the motor model under a continuous exposure instruction

In the questionnaire, while 63% of the students remarked that S3D helped understanding the structure, 3 students commented that they were too much attracted by the visual components rather than they could concentrate on the consideration of the physical mechanisms of motor. This implies that S3D helps to understand a complex spatial structure easily, but it might not always beneficial to let the learner consider the content in depth.

Table 1. Crosstabs of students' responses with regard to the effectiveness of S3D on understanding spatial structure and visual discomfort under continuous and intermittent S3D images

			Visual discomfort [%]			
		Exposure method	Disagree	Weakly agree	Agree	Strongly agree
Effectiveness to understand [%]	Disagree	continuous		2.9		1.4
		intermittent	3.3			
	Weakly agree	continuous		1.4	1.4	4.3
		intermittent		13.3	10.0	3.3
	Agree	continuous		10.0	20.0	22.9
		intermittent	10.0	10.0	6.7	23.3
	Strongly agree	continuous	1.4	4.3	11.4	18.6
		intermittent	3.3	10.0	3.3	3.3

Table 1 shows the results of students' responses on the effectiveness of S3D and the visual fatigue after watching rotational motion carefully, compared under continuous and intermittent exposure. Also, fig. 4 shows the bar charts of the table 1 for two exposure methods. Nearly all the students under continuous S3D exposure more or less got visual fatigue or visual discomfort to the S3D animation of rotational motions, although they admitted the effectiveness of it on learning. Under the intermittent exposure method, rate of those who disagree and weakly agree with the onset of visual discomfort was raised remarkably. 33.3% of the students did not feel strong discomfort, but felt sufficient effect on spatial recognition. However, 13.3% of the students responded as "weakly agree" to both of the questions. They have a capacity to watch more S3D to establish understanding.



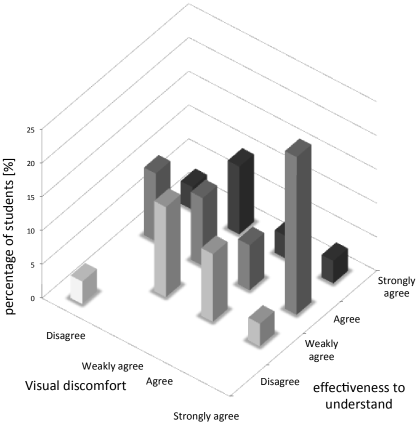


Fig. 4. Students' responses on the visual discomfort and effectiveness of S3D display. Left: students under continuous exposure of S3D images. Right: students under intermittent exposure of S3D images.

3.2 Effect of Short-Time Exposure of S3D on the Recognition of 3D Structure

In order to consider a proper way of S3D utilization to stimulate students' interest and facilitate spatial recognition, avoiding visual discomfort, detailed examinations on S3D rotational motion images are required.

Besides the stereopsis, the rotational motion of object stimulates the recognition of spatial structure even when one has only the projected images of a motion. Table 2 shows the average scores of the two-lines rotation test. The test was carried out for 11 university students around age 20, and a male of age 53. A noticeable person-to-person diversity in the scores were found.

Table 2. Crosstabs of students' responses with regard to the effectiveness of S3D on understanding spatial structure and visual discomfort under continuous and intermittent S3D images

	non-stereoscopic display	pre (1 sec) - exposure of S3D	S3D continuous exposure
average (% rate of correct answers)	67	67	73
standard deviation	11	8	11

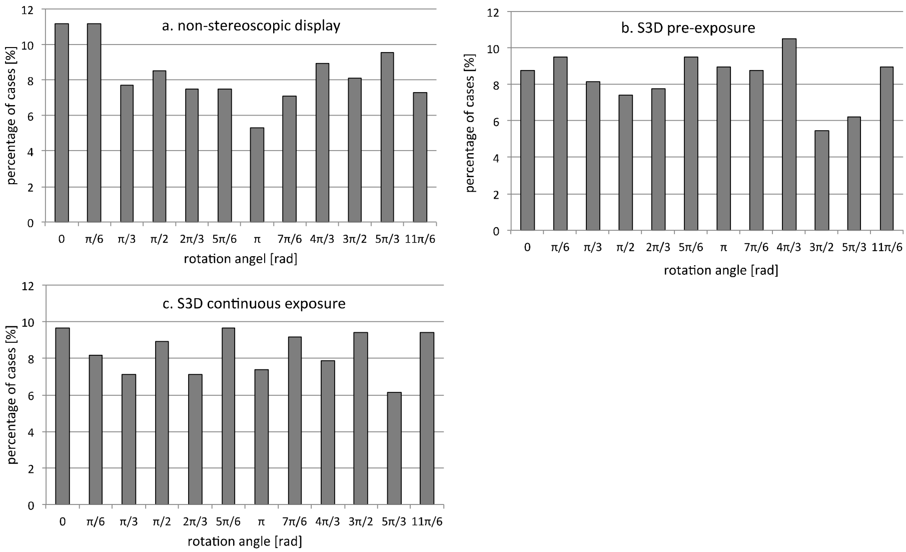


Fig. 5. Histograms of the percentage rates of incorrect choice cases in the 3D recognition test at various rotation angles for non-stereoscopic display, pre-exposure of S3D and continuous exposure of S3D

As seen in table 2, the average rates of choosing collect lines in non-stereoscopic display and 1 sec exposure of S3D before rotation were almost the same. This result indicates that the animated rotational motion helps to build the recognition of spatial structure. At first sight, this effect is strong enough to establish spatial recognition that the supplemental pre-exposure of S3D images did not affect when the exposure is short-time. The rate increased for continuous S3D exposure.

Here we proceed to more details. Figure 5 shows the histogram of the rates of incorrect choices at various rotation angles. The rate of choosing incorrect line was higher at small angle of rotation since less information was provided from small angle rotation. However, this tendency decreased in the pre-exposure of S3D. This is because that spatial structure is recognized before rotation. The failure histogram looks nearly flat for the rotation angles under the continuous exposure of S3D.

Figure 6 shows the rate of incorrect choices at various distances between lines. The distance was defined as the difference of center positions of lines along with the depth direction. The difference of depths of two lines is difficult to distinguish when the distance between them is small both for the rotating images and the S3D images. As seen in the figure, profiles of histograms in the non-stereoscopic and the short-time S3D exposure cases were nearly equivalent. However, in the cases of S3D continuous exposure, the range of the distances in which the failure frequently occurred was seen restricted within 1/10 of the length of the side of fixed cubic frame.

These results imply that we may find an appropriate effect on the spatial recognition even by a second of S3D exposure, avoiding visual fatigue due to long exposure. Detailed study on the duration of S3D effect after exposure is required. Use of S3D image has possibility to leverage the learning contents if the contents creators are more aware of the spatial recognition.

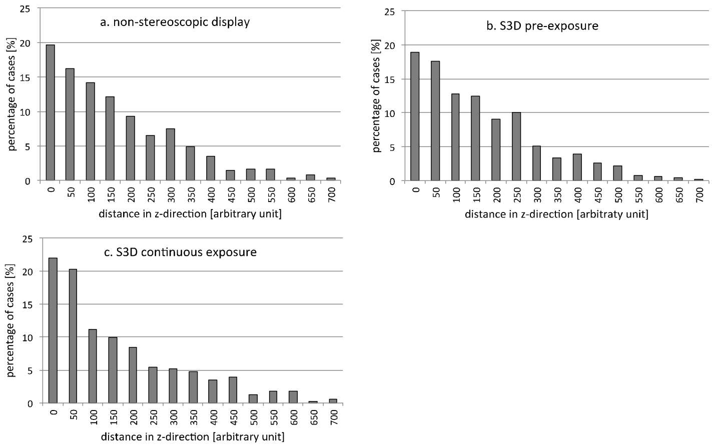


Fig. 6. Histograms of the percentage rates of incorrect choice cases in the 3D recognition test at various distances of two lines for non-stereoscopic display, pre-exposure of S3D images and continuous exposure of S3D display

4 Concluding Remarks

It was suggested that a control of S3D exposure was required in the sense of the spatial recognition, concentration to the content, and visual discomfort. It was also suggested that even a very short-time exposure of S3D helped a viewer's spatial recognition. More accumulation of knowledge is expected for the valuable application of S3D as an interface of the learning materials.

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