Original Article

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Evaluation of usefulness of 3D views for clinical photography

Masatoshi Jinnin*, Satoshi Fukushima, Shinichi Masuguchi, Hiroki Tanaka, Yoshio Kawashita, Tsuyoshi Ishihara, Hironobu Ihn

Department of Dermatology and Plastic Surgery, Faculty of Life Sciences, Kumamoto University, Kumamoto, Japan.

Summary **This is the first report investigating the usefulness of a 3D viewing technique (parallel viewing and cross-eyed viewing) for presenting clinical photography. Using the technique, we can grasp 3D structure of various lesions (*e.g.* tumors, wounds) or surgical procedures (*e.g.* lymph node dissection, flap) much more easily even without any cost and optical aids compared to 2D photos. Most recently 3D cameras started to be commercially available, but they may not be useful for presentation in scientific papers or poster sessions. To create a stereogram, two different pictures were taken from the right and left eye views using a digital camera. Then, the two pictures were placed next to one another. Using 9 stereograms, we performed a questionnaire-based survey. Our survey revealed 57.7% of the doctors/students had acquired the 3D viewing technique and an additional 15.4% could learn parallel viewing with 10 minutes training. Among the subjects capable of 3D views, 73.7% used the parallel view technique whereas only 26.3% chose the cross-eyed view. There was no significant difference in the results of the questionnaire about the efficiency and usefulness of 3D views between parallel view users and cross-eyed users. Almost all subjects (94.7%) answered that the technique is useful. Lesions with multiple undulations are a good application. 3D views, especially parallel viewing, are likely to be common and easy enough to consider for practical use in doctors/students. The wide use of the technique may revolutionize presentation of clinical pictures in meetings, educational lectures, or manuscripts.**

Keywords: Dermatology, plastic surgery, tumor

1. Introduction

3D or stereoscopy is technology capable of making the illusion of depth in an image and showing three-dimensional visual information. Until recently, convincing practical use of stereoscopy could only be seen in small fields such as simulators and visualization devices for a long time. However, 2010 was the year for 3D movies, and the introduction of 3D television to the public consumer market, which has been compared to the transition from black-and-white to color TV, and may be based on the success of some 3D movies in cinemas (*1*). In the near future, the application of 3D technology will be extended in various fields, especially in entertainment and education.

On the other hand, in the medical field, stereoscopy hovers at a level of limited use. For example, in the fields of dermatology and plastic surgery, it is important to grasp the 3D structure of the skin but sometimes difficult to obtain 3D information from 2D pictures. Our aim is to apply 3D views to decrease discrepancies in the grasp of 3D structure between actual clinical presentation and 2D clinical photos; *e.g.* at the exhibition of various lesions or operative procedures in scientific papers and poster sessions. In this study, we tried to evaluate the usefulness of 3D stereoscopy for clinical photography and found the best way to give 3D information to clinical photos using a questionnaire-based survey.

**Address correspondence to:*
Dr. Masatoshi Jinnin, Department of Dermatology and Plastic Surgery, Faculty of Life Sciences, Kumamoto University, 1-1-1 Honjo, Kumamoto 860-8556, Japan.
e-mail: mjin@kumamoto-u.ac.jp

2. Materials and Methods

2.1. *Creating stereograms for parallel viewing or cross-eyed viewing*

There are two methods for viewing a stereogram without glasses/headgear and any cost: parallel view format and cross-eyed view format. The former technique requires that the eyes take a relatively parallel angle. For cross-eyed viewing, the viewer has to cross his eyes (both eyes turn inward toward the nose). As shown in Figure 1A, to create a stereogram, two pictures (stereo pair) were taken from a slightly different angle – one from the right eye view and another from the left eye view. Then, the two different pictures were placed next to one another (Figure 1B). For parallel viewing, the picture that was taken from the right side was placed on the right, and the picture taken from the left side was placed on the left. For cross-eye viewing the two pictures were swapped around.

2.2. *Subjects*

Several stereograms with a questionnaire form were sent to 23 doctors and 3 medical students (18 males and 8 females; age range 23-51 years) randomly chosen from the Department of Dermatology and Plastic Surgery, Kumamoto University.

2.3. *Training for stereoscopy*

If the respondents to the survey have acquired neither parallel viewing nor cross-eyed viewing, we asked them to practice for less than 10 minutes based on the following procedure:

1) Parallel viewing
a) Bring your face close to the picture and get relaxed.
b) Try to look and focus at a distance behind the picture. Four blurred pictures (or 'black spots' for the aid of stereoscopy; see Figures 2A-2I) should be seen.
c) Pull the face back slowly away from the picture (20-50 cm), until the two middle pictures (or black spots) overlap together. Gradually, eyes will focus on the overlapped pictures as well as black spots and the brain will combine them into a 3D image.

2) Cross-eyed viewing
a) Keep distance of 20-50 cm from the picture and get relaxed.
b) To indicate to your eyes where to focus, bring your forefinger to the middle between you and the picture. Focus both your eyes on it.
c) While focusing on the finger, four blurred pictures (or black spots) should be seen at the same time.
d) Keep the focus and move your finger slowly between you and the picture back and forth until the two middle pictures (or black spots) overlap.
e) When you find the correct focal position and perceive the blurred 3D image, modify the focus slightly until a sharp and clear image is obtained.
f) Shift your attention from your finger to the pictures slowly.

2.4. *Questionnaire design*

The respondents to the survey capable of stereoscopy were asked to decide to use only one method (parallel viewing or cross-eyed viewing) and were requested to see 9 stereograms (Figures 2A-2I). After that, they were also asked to fill in a simple questionnaire as described below.

The questionnaire was designed with questions concerning age, sex, ease of obtaining sense of depth from each stereogram, evaluation of usefulness of stereograms for clinical use to grasp 3D structures, and visual fatigue caused by the stereoscopy.

Q1) On which stereograms could you perform stereoscopy easily? (Select all that apply)
Q2) Which stereograms gave a different impression about depth of lesion from the 2D picture? (Select all that apply and describe the reason).
Q3) Do you think stereoscopy is useful to grasp 3D structure of lesions?
Q4) On how many stereograms could you perform stereoscopy without visual fatigue?

2.5. *Statistical analysis*

All questions were analyzed and expressed as percentage of completed questionnaires. Statistical analysis was carried out with a Mann-Whitney *U*-test for comparison of medians and Fisher' exact probability test for analysis of frequency. p values less than 0.05 were considered significant.

3. Results

3.1. *Stereo images*

We considered two methods are suitable for viewing a stereogram in a scientific paper or poster presentation: parallel view and cross-eyed view formats, because they do not need any costs or optical aids for stereoscopy. We prepared 9 pictures (Figures 2A-2I) with different features. Figure 2A is the picture of tense blister of a burn representing a raised lesion, whereas Figure 2B, a post-operative scar of dermatofibrosarcoma protuberans represents a depressed lesion. Figure 2C displays a depressed geographic skin ulcer, and stereoscopy can reveal the lesion has elevated edges caused by epithelization. Figure 2D also shows keloid with both raised and depressed areas, which is obvious

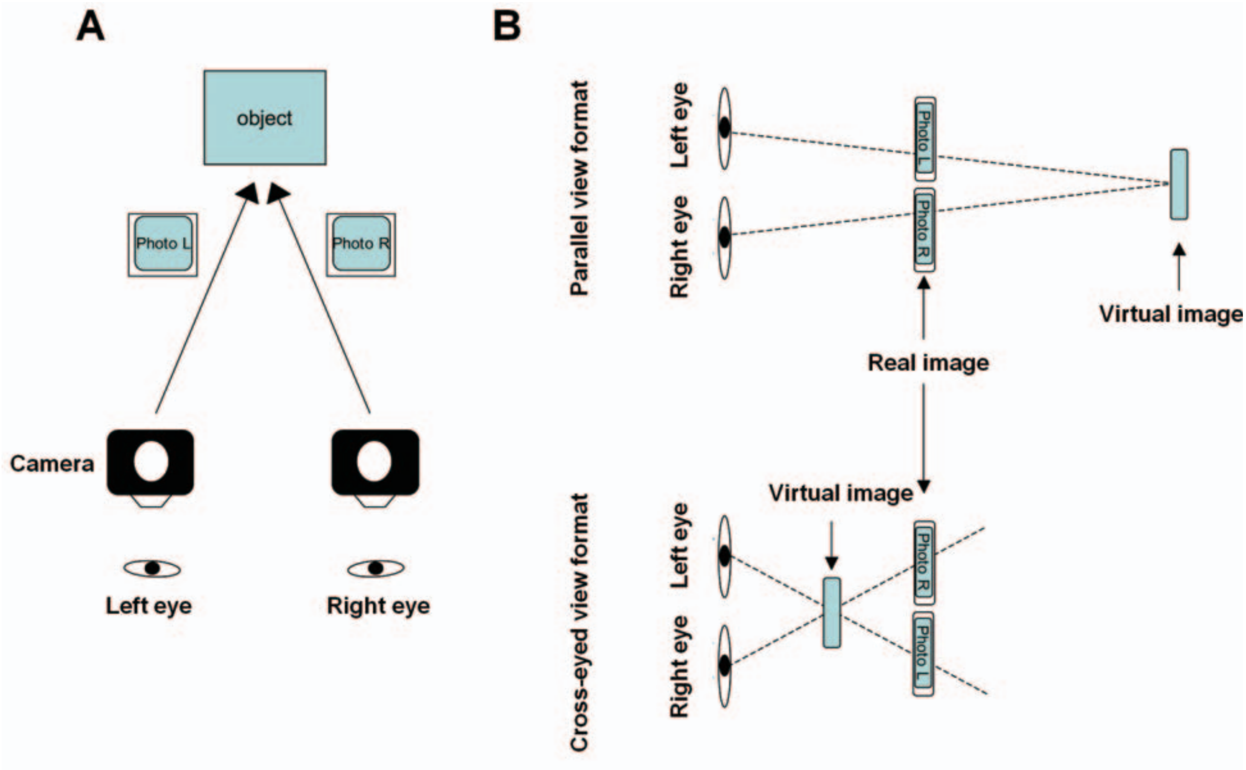

Figure 1. (A) Two pictures for stereograms. Two pictures (stereo pair) were taken from a slightly different angle - one from the left eye view (photo L) and another from the right eye view (photo R). **(B) Creating stereograms.** For parallel viewing, the left eye is forced to look only at the left picture, and the right eye is forced to look at the right one. The picture taken from the left side (photo L) was placed on the left, and the picture taken from the right side (photo R) was placed on the right. Virtual image is perceived behind the real images. For cross-eyed viewing, the left eye should look at the right eye-intended picture, and the right eye at the left. The picture taken from the left side (photo L) was placed on the right, and the picture taken from the right side (photo R) was placed on the left. Virtual image is perceived in front of the real images.

by 3D stereoscopy but not on the 2D photo. Figure 2E shows two raised lesions (nevus and seborrheic keratosis) with different heights, which is clearer by stereoscopy. Figures 2F-2I are pictures of 3D structures of operative procedures, which are sometimes difficult to understand; Figure 2F is the picture of an axillary lymph node dissection with considerable depth in the surgical field. Figure 2G shows complicated vessel structure in an inguinal lymph node dissection. Figure 2H is resection of dermatitis papillaris capillitii of the scalp and the grasp of 3D structure is disturbed by the hair. And Figure 2I is a picture of an operation of necrotizing fasciitis of the buttock, which has complicated muscle structure.

3.2. *Evaluation of usefulness of 3D stereoscopy*

Among the 26 respondents to the survey, 15 (57.7%) had already acquired stereoscopy; 5 subjects (19.2%) had acquired both parallel views and cross-eyed views, 5 (19.2%) had only parallel views, and 5 (19.2%) had only cross-eyed views. Interestingly, an additional 4 respondents (15.4%) could learn parallel views, not the cross-eyed view method, using training for less than 10 minutes. There is no statistically significant difference in age and sex between subjects capable of stereoscopy and those not.

The 19 subjects capable of stereoscopy were asked to decide to use only one method and were requested to see 9 stereograms (Figures 2A-2I). Among the 19 subjects, 14 chose parallel views and only 5 chose cross-eyed views; All 5 subjects capable of both parallel views and cross-eyed views chose the former technique. Subjects who decided to use parallel views selected Figure 2E (10/14 = 71.4%) and Figure 2C (9/14 = 64.3%) as the answer for Q1 about the ease of obtaining a 3D image from each stereogram (Table 1). They also chose Figure 2C (6/14 = 42.9%) and Figure 2E (4/14 = 28.6%) as well as Figure 2D (3/14 = 21.4%) as the answer for Q2 about the usefulness of each stereogram; The reasons subjects described were 'epithelization of the edge of ulcer was more clearly observed by stereoscopy' for Figure 2C, 'the depressed area (see Figure 2D-iii) was not obvious in the 2D picture' for Figure 2D, and 'he difference of height between two skin tumors (see Figure 2E-iii) were recognized better in the stereogram' for Figure 2E.

On the other hand, 5 cross-eyed view users selected Figure 2D (4/5 = 80.0%) and Figure 2E (4/5 = 80.0%) for Q1. Also, Figure 2E (3/5 = 60%) and Figure 2D (1/5 = 20%) were chosen for Q2. Taken together, there was no significant difference in the results of questionnaire

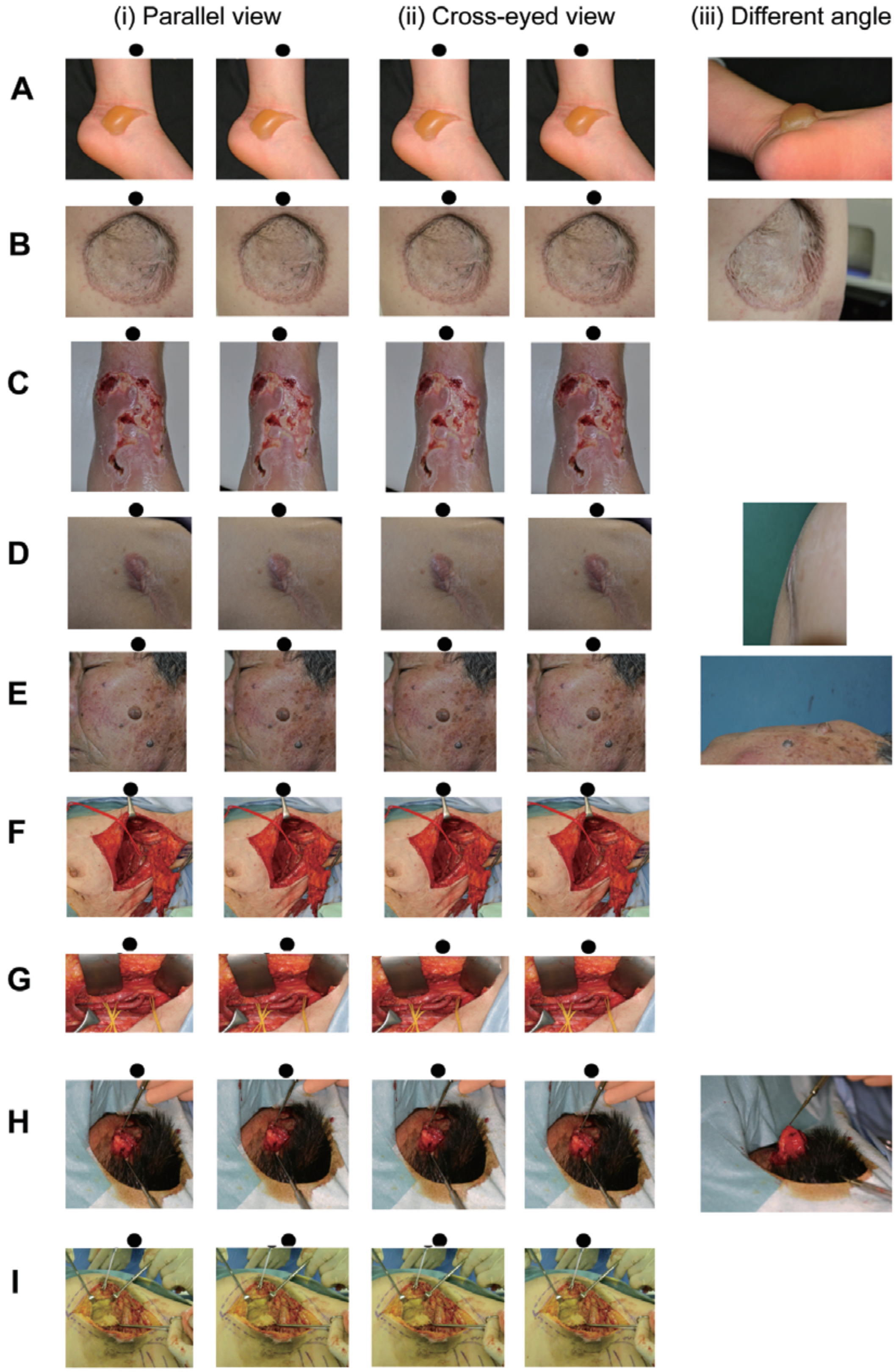

Figure 2. (i) for parallel view, (ii) for cross-eyed view, (iii) picture from different angle to show the height/depth of lesion. Black spots above the stereo pair were an aid for stereoscopy. (A) Blister of left ankle. The picture represents a raised lesion. **(B) Post-operative scar of dermatofibrosarcoma protuberans on the back.** The picture represents a depressed lesion. **(C) Leg ulcer.** Depressed lesion of skin ulcer with elevated edges caused by epithelization. **(D) Keloid on right shoulder.** The lesion has both raised and depressed areas. **(E) Nevus (left) and seborrheic keratosis (right) of the face.** The two tumors have different heights. **(F) Operative procedure of left axillary lymph node dissection.** This picture is difficult to grasp 3D structure on the 2D picture because of considerable depth in the surgical field. Thoracodorsal artery and vein were marked by red tape. **(G) Operative procedure of left inguinal lymph node dissection.** Arteries and veins were indicated by yellow tape. **(H) Operative procedure of resection of dermatitis papillaris capillitii on scalp.** The grasp of 3D structure is disturbed by the hair. **(I) Operative procedure of necrotizing fasciitis of buttock.** The area has complicated muscle structure. Yellowish tissue at the center is necrotic muscle.

Table 1. Results of the questionnaire survey

Items	Parallel view users (*n* = 14)	Cross-eyed view users (*n* = 5)	Total (*n* = 19)
Q1			
Figure 2A	7 (50.0%)	2 (40.0%)	9 (47.4%)
Figure 2B	1 (7.1%)	1 (20.0%)	2 (10.5%)
Figure 2C	9 (64.3%)	2 (40.0%)	11 (57.9%)
Figure 2D	5 (35.7%)	4 (80.0%)	9 (47.4%)
Figure 2E	10 (71.4%)	4 (80.0%)	14 (73.7%)
Figure 2F	1 (7.1%)	0 (0.0%)	1 (5.3%)
Figure 2G	0 (0.0%)	0 (0.0%)	0 (0.0%)
Figure 2H	4 (28.6%)	0 (0.0%)	4 (21.1%)
Figure 2I	2 (14.3%)	1 (20.0%)	3 (15.8%)
Q2			
Figure 2A	1 (7.1%)	0 (0.0%)	1 (5.3%)
Figure 2B	0 (0.0%)	0 (0.0%)	0 (0.0%)
Figure 2C	6 (42.9%)	0 (0.0%)	6 (31.6%)
Figure 2D	3 (21.4%)	1 (20.0%)	4 (21.1%)
Figure 2E	4 (28.6%)	3 (60.0%)	7 (36.8%)
Figure 2F	1 (7.1%)	0 (0.0%)	1 (5.3%)
Figure 2G	0 (0.0%)	0 (0.0%)	0 (0.0%)
Figure 2H	1 (7.1%)	0 (0.0%)	1 (5.3%)
Figure 2I	2 (14.3%)	0 (0.0%)	2 (10.5%)
Q3	13 (92.9%)	5 (100.0%)	18 (94.7%)
Q4 (No. of stereograms)	4.8 ± 1.4	5.0 ± 2.3	4.9 ± 1.6

Unless indicated, values are number of patients which selected each figure as the answer for each question.

between parallel view users and cross-eyed view users. Almost all of the 19 subjects capable of stereoscopy (18/19 = 94.7%) pointed out at least one stereogram as the answer for Q2, and also answered that 3D stereoscopy is useful (Q3). In 14 subjects who used parallel views, 7 (50.0%) did not feel visual fatigue, but the other 7 felt after 2-5 stereoscopy (Q4). In 5 subjects who used cross-eyed views, 1 felt fatigue after seeing 1 stereogram, and another did after 5 stereoscopies. The mean number of stereograms subjects could perform stereoscopy without visual fatigue was 4.8 ± 1.4 (mean ± S.D.) in parallel view users and 5.0 ± 2.3 in cross-eyed view users, and there was no statistically significant difference.

4. Discussion

Several systems have been used to bring the illusion of depth to pictures or movies. The anaglyph format, historically the earliest method used in various media, is made up of two different color layers for each eye. Glasses used consisted of two lenses with different colors (such as red and cyan), and the two layers are merged by the visual cortex of the brain to produce the stereoscopic 3D effect. Although the anaglyph format is much easier than the parallel view and cross-eyed view formats, it usually has problems in reproduction of color. The polarization format, especially circular polarization, is often used in the 3D movie system, but it needs polarized 3D glasses/headgear and a silver screen to maintain polarization. Frame sequential 3D or side by side 3D technology also needs active shutter glasses and is not likely to be suitable for figure presentation in scientific papers or poster sessions. On the other hand, most of us have to train our eyes to see the illusion by parallel viewing or cross-eyed viewing. In addition, finally, the persons with visual impairments affecting one or both eyes may not be able to perceive the sense of depth in spite of training, which is a common problem among most types of 3D technology. Moreover, these methods only can be used when the photos are printed in books, papers, or posters which are able to be seen at a near distance, but are not available for presentation from stage for a large audience. However, we regarded these methods as the most practical because of their low cost and the needlessness for any external aids for viewing including glasses/headgear. Our survey revealed 57.7% of the subjects had acquired stereoscopy and an additional 15.4% could learn parallel viewing with 10 minutes training, whereas the remaining 26.9% could not perform stereoscopy in the end. To increase the saturation level of stereoscopy in doctors/students and to consider practical uses, longer training of more than 10 minutes, establishment of training methodology, and preparation of easy and simple examples to learn stereoscopy may be needed. To note, by seeing each one of the two pictures for a stereogram, someone who cannot get a 3D image ultimately in spite of such training still can enjoy clinical photos by usual picture presentations. Thus, there may be no demerits utilizing stereograms for clinical presentations.

One of our interests was which method of parallel or cross-eyed viewing is better to be utilized for figure presentation of various lesions and surgical procedures. The percentages of subjects who had originally acquired parallel viewing was the same as those who acquired cross-eyed viewing (38.4%), but additional subjects could learn parallel viewing, not cross-eyed viewing, easily by training, and the number of subjects who decided to use parallel views was greater than those who used cross-eyed views (53.8% *vs.* 19.2%). Furthermore, although an advantage of cross-eyed viewing is that a much larger and wider stereo pair can be merged together, virtual images by cross-eyed viewing was perceived in front of the real images but smaller than that of parallel views; our brain expects closer objects should be perceived larger. When the closer object is actually the same size as a distant one, the visual cortex decides it should be smaller. Considering that there was no significant difference in the results of the questionnaire between subjects with parallel views and cross-eyed views, taken together, parallel views may be preferable to present stereograms. Especially, based on the reasons subjects suggested, lesions with multiple undulations (Figures 2C, 2D and 2E), not simple and single raised or depressed lesions (Figures 2A or 2B), may be good applications for 3D stereoscopy.

Our questionnaire revealed that 94.7% of subjects capable of stereoscopy felt stereograms are useful. Most recently, autostereoscopic 3D television which does not need special headgear/glasses on the part of the viewer, or 3D cameras started to be commercially available. Of course, they will take a long time to be applied for academic use and may not be useful for clinical presentations in scientific papers or poster sessions. However, because 3D technology will generally and increasingly be paid attention to by such new products, parallel viewing or cross-eyed viewing may also be more acceptable and can be introduced easier than before.

Basically, stereoscopy is not thought to be harmful and does not cause visual disorders (*2-6*), and is even utilized for treatment of binocular disorders by orthoptists or vision therapists (*1*). However, as another common problem of all 3D techniques, long time 3D view may cause visual discomfort and visual fatigue; the subjects in our study felt visual fatigue after an average of 4.9 stereoscopy views. Thus, to avoid visual fatigue, the number of stereograms in one presentation should be less than 4. Furthermore, poor quality of stereograms may further such visual discomfort and fatigue. Given that the stereograms selected as the answer for Q1 and Q2 were similar, the quality of each stereogram may also affect both understanding of 3D structure and visual comfort significantly. For a successful and comfortable introduction of increased numbers of stereograms, quality of stereograms must be improved. Larger studies are needed in the future.

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