An Explanation of Depth Effects in a Novel Illusion Through Binocular Half-Occlusion

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by

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ABSTRACT

Three studies examined a visual depth illusion (the "bookmark illusion") and showed that it is best explained by binocular texture element occlusion-disocclusion disparity. Barrand (1979) also refers to occlusion-disocclusion disparity as “gain or loss disparity” (GOLD). Other predictions or explanations of the binocular depth illusion such as interposition, classical stereopsis, and progressive occlusion-disocclusion were generally ruled out. The illusion consists of an opaque shape adhered to a special translucent plastic “bubble sheet”. The bubble sheet is embossed on both sides with tiny optical lenses that produce oval rings or bubbles. The illusion reverses apparent depth depending on whether viewed binocularly or monocularly. Monocularly, the shape appears to be floating above or even with the bubble sheet. Binocularly, the shape appears to be sunk into the bubble sheet. Experiment 1 quantified the magnitude of the illusion under a variety of viewing conditions with 18 observers. Observers reported whether the opaque circle appeared to be floating above, even with or sunk into the bubble sheet, in a 2 (monocular vs. binocular viewing conditions) X 3 (static, translating, or rotating movement conditions) X 3 (distances of 35, 50 or 65 cm) factorial design. Analysis of variance indicated significant main effects of viewing conditions, $F(1,15)=34.752$, $p<.001$, and for movement conditions, $F(2,30)=58.308$, $p<.001$. There was also a significant interaction between

monocular/binocular viewing and movement conditions ($F[2,30]=25.213$, $p<.001$). Viewing distance had no effect on the strength of the illusion. Observers consistently reported that the circle appeared to be sunk into the bubble sheet when viewed binocularly, and even with or floating above the bubble sheet when viewed monocularly. GOLD is the only explanation that can account for the circle appearing to be sunk into the bubble sheet. Experiment 2 tested the binocular depth effect by reversing the display where the plastic "bubble sheet" was covered with black gummed paper. A hole showed a circular region of the bubble sheet. GOLD predicted that the bubble sheet should appear to bulge out over the edges of the black opaque surface around it. The 22 observers were assigned to two groups (free response or timed [t=30 sec]), and viewed the display under the same conditions as Experiment 1, but at only one distance of 50 cm. The procedure resulted in a 2 (monocular vs. binocular viewing conditions) X 3 (static, translating, or rotating movement conditions) X 2 (groups; free response vs. 30 sec. timed) factorial design. Analysis of variance indicated significant main effects of viewing conditions ($F[1,18]=23.867$, $p<.001$), and movement conditions ($F[2,36]=24.350$, $p<.001$). There was also an interaction between monocular/ binocular viewing and movement conditions ($F[1,18]=4.711$, $p=.044$). The results of the experiment indicated that observers consistently reported that the bubble sheet appeared to bulge out of the surface only for the binocular viewing condition, consistent with the GOLD hypothesis. Experiment 3 tested the effects of contour orientation on depth impressions for binocular viewing. Since all explanations for binocular depth require horizontal disparity of retinal images, contours that are most vertically oriented should produce the most pronounced depth effects and contours oriented closer to horizontal should yield less pronounced depth effects. Observers should report seeing the stripe across the bubble sheet as being more sunk in as it approaches vertical and a lesser effect at stripe angles closer to horizontal. Thirty-four observers binocularly viewed a black stripe attached to the same translucent "bubble sheet" used in Experiments 1 and 2. The stripe was displaced from horizontal by various angles (0°, 22.5°, 45°, 66.5°, 90°, 112.5°, 135°, 157.5°) in seven randomized trial blocks. The design resulted in a 2 (groups; free response vs. 15 sec. timed) X 2 (procedures; standard vs. modified [angle order and visual illustration of rating scale]) X 8 (angles) X 7 (trial blocks) factorial design. Analysis of variance indicated significant main effects for angles ($F[7,210]=3.525$, $p<.001$), and viewing time group ($F[1,30]=24.848$, $p<.001$). There was also an interaction between angle and trial block ($F[42,1260]=9.003$, $p<.001$). The results indicated that observers reported the stripe as being sunk deeper into the "bubble sheet" when viewed at angles closer to vertical. This is consistent with the prediction that horizontal disparity of the display would produce the most pronounced depth effect.

On the whole, these studies indicated that the bookmark illusion (an opaque occluding patch seen as sunk into a special lenticular "bubble sheet" when viewed binocularly but even with or floating above the sheet when viewed monocularly) is best explained by the GOLD mechanism. The effect may be used in a number of practical applications and provide a simple means to test other aspects of the GOLD hypothesis.

INTRODUCTION

This research consisted of an analysis of a novel illusion commonly sold as a bookmark. Experimental studies attempted to explain its observable depth effects using various approaches to depth perception. An example of the bookmark is shown in Figure 1. The illusion consists of an opaque circle adhered to a translucent plastic sheet embossed on both sides with tiny optical lenses that produce oval rings (or "bubbles"), about 6 X 12 mm wide. When the illusion is viewed with two eyes (by individuals with normal binocular vision), the circle appears sunk into the bubble sheet, but when viewed with one eye, appears to be floating on top of or even with the bubble sheet.

The bookmark illusion is unique in that a monocular depth effect (even with or floating above its background) and a binocular depth effect (sunk into the background) are both achieved by the same display. No other known display produces both a monocular and a binocular depth effect, making this quite an interesting phenomenon to study. The bookmark studied is relatively widely known , but no explanation for its observable effects has apparently been offered.

This is an interesting analysis for several reasons. Illusions have been known to exist and have been studied for a long time. They have been of interest for their own sake and as a means to understanding perception in general (Wade, 1982).

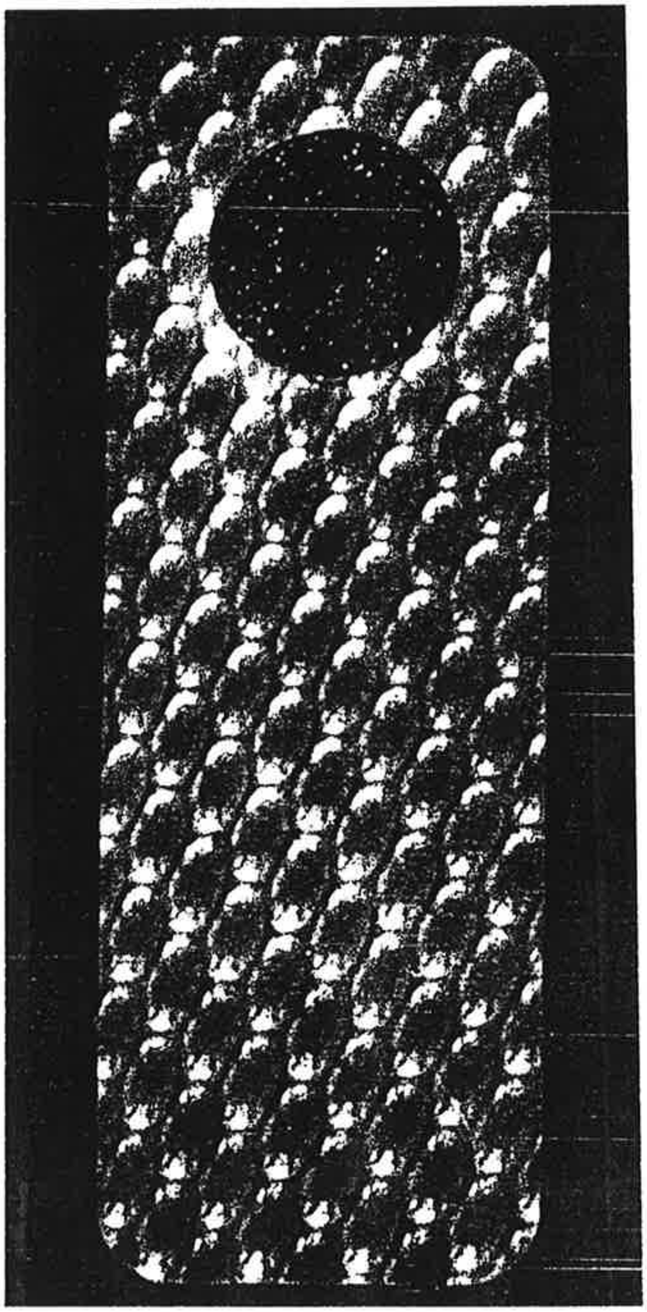

Figure 1. Sample of the novel illusion commonly sold as a bookmark. The circle appears even with or to float above the bubble sheet when viewed monocularly, but appears sunk into the bubble sheet when viewed binocularly.

Depth perception is also a problem that psychologists have attempted to understand and explain for many years. In some sense, depth perception is always illusory, in that we gain the experience of a three-dimensional environment from two-dimensional retinal images. Despite some centuries of attention to this problem, new explanations for depth perception are still being discovered (Anderson & Nakayama, 1994; Barrand 1979).

The bookmark illusion, a two-dimensional display, gives two contradictory impressions of three-dimensionality or depth. The task in the present investigation was to attempt to account for these illusory effects.

Three separate experiments were designed to explore the perceptual phenomena associated with this unique illusion. Recent theoretical work on binocular depth perception has suggested an explanation, binocular "gain or loss disparity" (GOLD), for what observers would report (Anderson & Nakayama, 1994; Barrand, 1979). There are also several other candidate explanations that might apply here such as classical stereopsis, interposition, or progressive occlusion-disocclusion. For a variety of reasons, it appears that this illusion is best explained by GOLD, as will be shown below.

I will discuss monocular illusions of depth, binocular two dimensional displays that give impressions of depth, and several theories that have been offered to explain depth perception.

Monocular Depth Illusions

Illusions of depth have been investigated for almost 150 years (Wade, 1982). Most illusions are monocular, in that impressions of depth are apparent through viewing displays with only one eye. Artists have used monocular illusions to their advantage to represent three-dimensional environments (Wade, 1982). Collectively, these have been called pictorial cues for depth (Matlin & Foley, 1992).

Simple illusions of depth have been created using wavy patterns and circular lines. Figure 2 is an example of a simple monocular illusion created by circular lines. The circle can be seen as a cone, with the observer looking down onto it from above, or as a funnel into which the observer is looking. No matter what perception of depth is seen (funnel or cone), the depth effect can be achieved through monocular vision.

Another illusion can be created by using figure-ground relationships which show impressions of depth for monocular vision. Different impressions are achieved depending on whether the observer focuses more on the foreground or on the background of the image. One common image used to demonstrate this phenomenon is the classic "faces vs. vases". The illustration can appear as a face or a totally different image (a vase) depending on which region of the display the observer takes to be figure (in the foreground) or ground (Gerow, 1992).

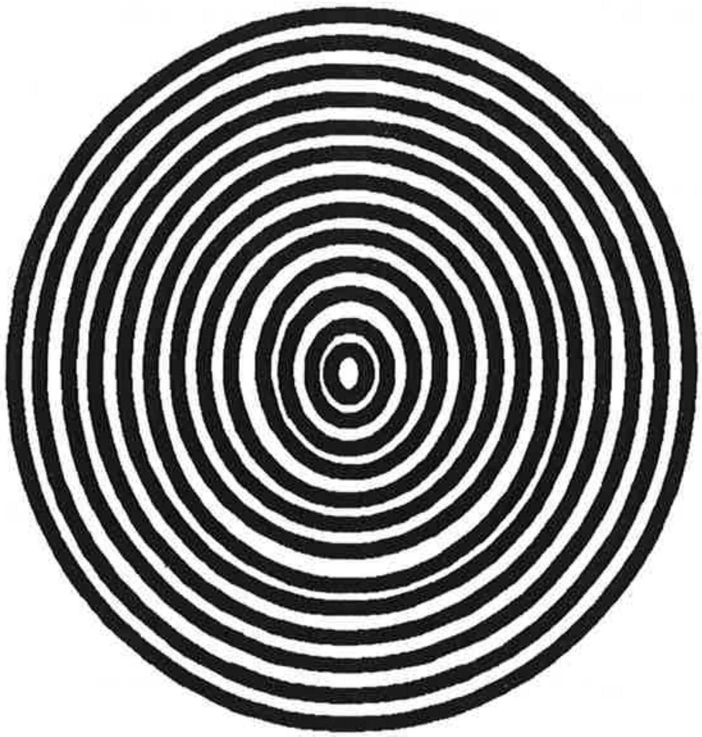

Figure 2. A common monocular illusion created through the use of circular lines. (Adapted from Wade, 1982).

Illusions of depth can also be achieved through a monocular cue for depth called interposition. Interposition is a pictorial cue that occurs when a closer object partially blocks the view of the (more distant) background. An impression of depth is thus observed. The bookmark contains an opaque object that indeed blocks our view of the bubble sheet behind it. But interposition doesn't account for why we see the object as being behind or sunk into the bubble sheet.

Reliable illusory monocular depth effects are also reported in displays that produce "subjective contours" (Kanisza, 1979). In these figures, some elements of the display are apparently covered up by an area that is not actually drawn into the display. A standard version shows three circles with a wedge cut out of each as if a triangle had been laid over the circles, the circles located at the "points" of the triangle. Actually, all an observer sees is the three "Pac-man" circles. But observers typically report seeing the triangle as well. The triangles's sides are seen as "subjective contours"--edges of the triangle that are not actually present. The illusory triangle is often reported to appear brighter than the surrounding area. The triangle is also reported to appear to float above the "Pac-man" circles and the sheet on which they are printed. (Anderson & Julesz [1995] report a variety of binocular effects related to subjective contours.) It is obvious that the effects are related to interposition.

Movement can also create monocular impressions of depth. A movie is one such example. The screen is two dimensional but movements on the screen give the impression of depth. The bookmark illusion can also give an impression of depth when moved. By holding the bookmark and turning it toward and away from oneself, one can see the occluding object appear to slide across the bubble sheet, giving a depth impression of the object being closer to the observer than the bubble sheet.

Proffit (1992) introduced evidence that binocular depth effects can also be achieved through stereo kinetic motion.The experimental studies included an analysis of the kinetic depth effect as shown by patterns moving on a turntable. Depending on the character of the movement, observers can see a moving planar figure as a moving three-dimensional form.

Binocular Illusions

Early researchers believed that all depth occurred through monocular vision of objects (Gulick & Lawson, 1976). Research into depth perception analyzed other illusions that are "binocular," in which an impression of depth occurs through viewing the illusion with both eyes. Early research by Da Vinci and Charles Wheatstone led to the investigation of binocular depth perception (Gulick & Lawson, 1976). Da Vinci had a general notion of binocular depth perception but didn't develop a theory to account for it. Charles Wheatstone studied stereopsis and later developed a model for stereoscopic depth perception.

Wheatstone invented the stereoscope as a tool to study binocular depth. A stereoscope is a device that allows the observer to view two separate images (one image to each of the eyes) and then the visual system fuses the two images (called a stereo pair) together into a single image where an impression of depth occurs. No depth is achieved by looking at the images separately or by viewing them monocularly. When the images are viewed with the stereoscope, an impression of depth is generally achieved. Stereoscopic studies led to a useful explanation for binocular depth perception called "classical stereopsis" which will be discussed later in more detail.

Another class of binocular depth illusions can be achieved through the use of random dot stereograms (Julesz, 1986). Two images (stereo pairs) are used to achieve a perception of binocular depth. On the display (computer generated) are a matrix of randomly placed dots that, when looked at monocularly, produce no image or depth effect. When the stereo pair patterns are fused, a difference (disparity) in what each eye sees is apparent, and a form is seen that gives an impression of depth.

Recent popularity of "Magic Eye" books (NE Thing, 1994) and posters leads one to believe interest in binocular illusions is rising. These illusions create a binocular impression of depth through the use of cleverly printed stereo pairs. The picture consists of computer enhanced colored stereogram images including carefully placed contours and lines. The contours and lines keep the viewer from seeing each of the separate stereo pair images. As the viewer looks at the image, the disparate portions of the image that are seen by the right and left eye separately, are fused together, to form a single three-dimensional image.

Antonio Puerta (1988) investigated displays in which binocular depth perception could be achieved through the use of "shadow stereopsis." The research involved observers viewing stereo pairs in which the images were different in an unusual way. Each image had an amount of shadow (or apparent shadow) cast by an object, available to each eye. The disparity was in the amount of shadow behind the object that each eye can see. The greater the "shadow disparity", the further above the surface the object casting the shadow appeared to be. When the images were fused by the observer, an illusion of binocular depth occurred. The interesting aspect of Puerta's display is the disparity between what is and is not available to the two eyes. The explanation of GOLD below involves a similar concept.

Vos (1960) introduced an analysis of depth effects based upon color stereoscopy. The study demonstrated that different effects of binocular depth can be achieved through variations in the color of objects. This variation in color (of a single image display) produces retinal disparity for points of different color, thus an effect of depth. The color stereoscopy studies (Vos, 1960) show an effect of depth in a single display as does the bookmark illusion. The bookmark illusion however, produces contradictory effects of depth for monocular and binocular vision which is not investigated in the color stereoscopy studies.

So, perceptual impressions of depth can come from two-dimensional displays viewed with one eye or with two eyes. But apparently no displays (except the bookmark) show the kind of switch in depth order (above or below the bubble sheet) when viewed with one vs. two eyes.

What can account for these impressions of depth? Several explanations can be offered such as classical stereopsis, static interposition, progressive occlusion-disocclusion and GOLD. Each of these explanations is described briefly below.

Classical Stereopsis

Classical stereopsis requires, in general, that some retinal image points lie at corresponding retinal locations, and that some retinal image points lie at non-corresponding retinal locations, but that all retinal image points match on the two retinas (Figure 3). Disparity refers to the difference in the distance between matched points on the two retinas, which occurs when those image points are projected from features at different physical distances from the eyes. The bookmark illusion studied presents a perplexing problem because the circle and the bubble sheet are at the same physical distance but appear not to be. In

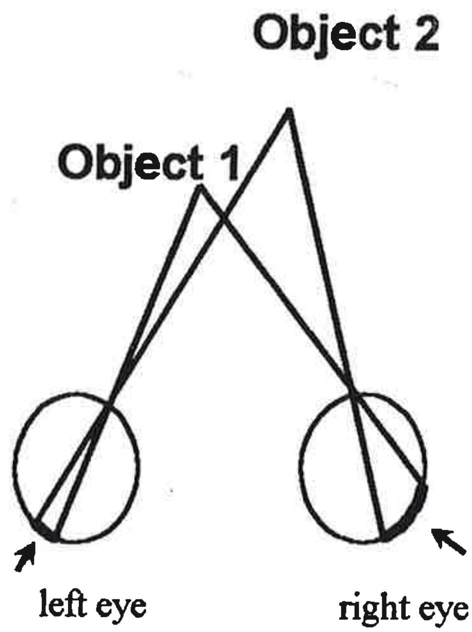

Figure 3. Classical stereopsis for binocular depth perception. The arrows illustrate retinal disparity that occurs from image points projected from objects at different physical distances from the two eyes (Adapted from Gulick & Lawson, 1976).

principle, all the object points should correspond to paired retinal image points in the same plane, and should produce no retinal disparity, thus no depth effect.

Static Interposition

Interposition is a (pictorial) cue for depth that occurs when a closer object partially blocks the view of the (more distant) background. Using Figure 1 as an example, we can see that the circle occludes a portion of the bubble sheet behind it. Interposition, therefore, should always have observers report that the circle is in front of the bubble sheet. The circle should always appear in front of, nearer the observer than, the bubble sheet surface. This presents a puzzling problem because looking at the circle binocularly, one sees the circle as being sunk into the sheet. Conversely, if the bubble sheet were to be seen through a hole in an opaque sheet, the edges of the sheet occlude portions of thebubble texture should at the edge of the hole. Thus, the bubble sheet should appear to be further from the observer than the occluding sheet. As is shown in Experiment 2 below, this does not happen.

Progressive Occlusion and Disocclusion

Impressions of relative depth can also be produced through movement (Halpern, 1991). Moving the bubble sheet produces this phenomenon. When moved, the "bubbles" of the bubble sheet seem to slide under the edge of the circle. Some bubbles at other edges appear to move out from under the circle (at the edge of the circle and edge of the bubble sheet). The edge where the circle meets the bubble sheet is important for obtaining an impression of depth (Kaplan, 1969). The edge of the circle is clearly seen and never appears to be covered up by the bubbles. The result should be that the circle always appears to be on top of the bubble sheet and never sunk into it. This progressive occlusion-disocclusion accounts for some of, but not all, the phenomena observed with this illusion, so yet another explanation is needed.

Again, if the bubble sheet is viewed through a hole in an opaque covering sheet, the bubble should appear to slide under the edges of the hole, presumably giving an impression of the bubble sheet behind the opaque sheet. This effect is tested in Experiment 2.

Binocular Gain-Or-Loss Disparity (GOLD)

Barrand (1979; see also Anderson & Nakayama, 1994) described occlusion-disocclusion disparity (Anderson and Nakayama use the term "half occlusion;" Barrand refers to GOLD) as a possible explanation for binocular depth perception. Barrand (1979) proposed that not only can there be position disparity of the images projected on the two retinas of the two eyes (as in classical stereopsis), but there is also disparity between the availability of texture to the two eyes (Figure 4). Depending on which texture elements are available to each eye, an object may appear as sunk into a hole in the surface or as nearer than

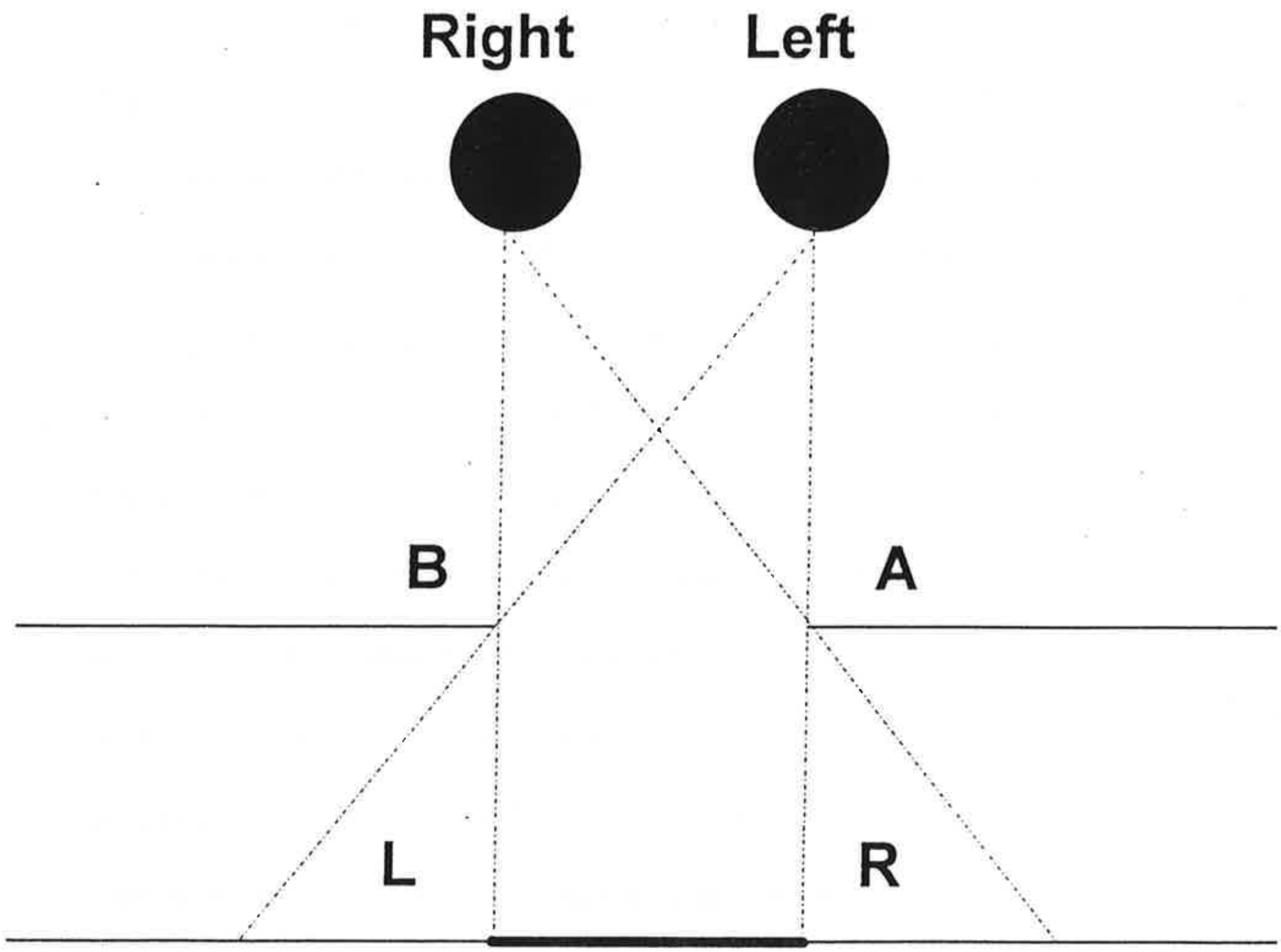

Figure 4. GOLD occurs between the two eyes. The eyes focus on points A and B which are at the edges or boundaries of the circle and at the same physical distances from both eyes. As the right eye focuses on points B and A it is able to see the (R) area which is not visible to the left eye. As the left eye focuses on points B and A it is able to see more of the disparate area (L) which is not visible to the right eye.

another surface (in front of or floating above the surface). By carefully inspecting the bookmark it appears as if more of the bubble sheet texture is available at the edge of the spot on the side opposite to each eye (the contralateral side). Disparity occurs between what each eye sees, thus an effect of depth is observed.

An object at the surface would show no gain-or-loss disparity because all he the same texture elements should be available to both eyes. Therefore, in the bookmark, the circle and background should appear to be in the same plane.

Some recent theoretical work (Anderson and Nakayama, 1994; Anderson & Julesz, 1995), explores new explanations for binocular depth that resemble GOLD. In a variety of tasks, Anderson and Nakayama (1994) showed that differences in the availability of observable texture to the two eyes produced predictable binocular depth effects. Barrand (1979), while describing the basic principle, did not work out details of the effects as Anderson and Nakayama (1994) have done. Barrand in fact presents little or no data to support the geometrical analysis he presents. The fact that an illusion (the bookmark illusion) exists, apparently based on these newer approaches to understanding binocular depth perception, is surprising. Experiments 1 and 2 explore this explanation.

Other theoretical work (Anderson and Julesz, 1995) researched the role that horizontal disparities play in binocular depth perception. In their studies stereograms were used to test the occluding contour and horizontal disparity depth effects. The greater the horizontal (side-by-side) retinal disparity, the greater should be the resulting depth impression. The clearest disparity should be found when the contours are vertical. When contours are at an angle, the depth impressions should be weaker. Experiment 3 discussed later investigated the effects of varying orientation on observed depth of a stripe through binocular viewing of the stripe at various angles. This differs from Anderson and Nakayama's (1994) work in that sequential binocular viewings of a stripe occur at different angles rather than by an image that is rotated or oriented before being viewed in a stereoscope.

The present paper reports the results of three studies. The first quantified the monocular and binocular depth effects seen when an opaque object is attached to the bubble sheet, and showed that the pattern of results is best explained by the GOLD concept. The second study used the GOLD hypothesis to predict a novel depth effect when the bubble sheet was viewed through a hole cut in an opaque sheet attached to the bubble sheet. The third study further demonstrated the binocular character of the depth effect by showing that the depth effect changes predictably with the orientation of contours occluding the bubble sheet.

EXPERIMENT 1

This experiment was conducted to identify whether the depth phenomena observed in the bookmark illusion are a result of binocular texture GOLD. Observers responded to a display similar in appearance to the bookmark illusion that reversed its apparent depth depending on whether it was viewed monocularly or binocularly. Observers should have reported seeing the object as "sunk into" the bubble sheet for monocular viewing, and even with, or floating in front of the bubble sheet for monocular viewing. Static interposition, progressive occlusion-disocclusion, and gain-or-loss disparity were examined to see which of these principles could account for the depth effect.

As described earlier, classical stereopsis cannot predict any depth effect in the bookmark illusion because the same single image is present to each eye; thus, observers would always judge the circle to be even with the bubble sheet. Static interposition would predict that the circle should be seen as in front of the bubble sheet for both monocular and binocular viewing. Progressive occlusion-disocclusion would predict that the circle would be seen in front of the bubble sheet under monocular viewing, when the display is translated or rotated. The GOLD hypothesis could predict the circle would be seen as sunk into the bubble sheet when the display is viewed binocularly only, not when viewed monocularly. With binocular viewing and translation or rotation, GOLD and progressive occlusion-disocclusion are in opposition, and it was not clear which would predominate.

Further, since any depth effect based on retinal disparity should vary with distance from the eye to the display, the GOLD depth effects predicted should be greater for closer distances and less for longer viewing distances. Table 1 summarizes all these predictions.

Method

Participants. Twenty-three undergraduate students from the Pembroke State University campus volunteered to participate in the study. Observers were primarily introductory psychology students and were given partial credit for participation. Observers were between 18 and 40 years of age. All observers were screened for normal visual functioning (uncorrected or corrected by eyeglasses) by a series of questions: Do you wear glasses? Do you wear bifocals or trifocals? Do you now suffer from or ever had crossed eyes? Do you now suffer from or ever had a lazy eye? Have you ever failed a motor vehicle eye exam? Do you have difficulty in seeing hidden 3-D "Magic Eye" posters? If yes, did you only have difficulty seeing them the first time? Five participants showed some visual deficit. Thus 18 observers were assigned to three viewing distance groups.

Equipment and materials. Observers all viewed a 6 cm diameter black circle constructed from black gummed paper adhered to a bubble texture sheet

Table 1

Possible Predictions/Explanations for the depth effect.

	Prediction of object's relative depth	
Theoretical principle	**Monocular viewing**	**Binocular viewing**
Classical stereopsis	**None**	**None**
Static interposition	**Floating**	**Floating**
Progressive occlusion-disocclusion (display translation or rotation)	**Floating**	**Floating**
Gain-or-loss disparity (static display)	**Floating**	**Sunk**
Gain-or-loss disparity (display translation or rotation)	**Floating**	**Sunk?**

(approximately 20 x 25 cm) embossed on both sides with tiny optical lenses that optically produce bright oval rings (or "bubbles"), about 6 X 12 mm wide. The bubble sheet and attached circle were mounted in a 25 X 25 cm cut-out white frame that was attached at the top to a metal rod. The display could be placed at one of three distances, 35, 50, or 65 cm, from the observer's eyes. The rod was supported by a set of pulley wheels attached to each side of the viewing box that allowed the display to be viewed static, translated, and rotated. A 1.25 diameter X approximately 75 cm wooden dowel rod was used to guide the translation of the display about 15-20 cm left and right from its center of alignment. A guide attached to the outside of the viewing box allowed for an approximately 30° rotation of the display (15° forwards and backwards from its perpendicular alignment to the observer's gaze).

The display was assembled in a wooden box that was 100 X 75 X 75 cm. The interior of the box was lined with white foamboard attached to a wood frame by Velcro. Attached to the front of the box was a viewing aperture (18 X 2.5 X 2.5 cm horizontal slot) that was located approximately 50 cm above the table supporting the apparatus. The slot allowed for both monocular and binocular viewing of the display. Painted black cardboard covers were inserted in front of the horizontal viewing slot to keep the observer from looking into the box before experimentation. The covers also allowed the horizontal viewing slot to be closed off to one eye for monocular viewing. Overhead fluorescent room lights illuminated the viewing box. The box was placed directly under the lights to minimize shadows on the display.

Procedure. Permission for conducting this research was granted through the Internal Review Board of Pembroke State University (Appendix A). Observers were briefed on the procedures for the experiment, and signed an informed consent form (Appendix B).

Observers were instructed to judge whether the black circle appeared to be in front of, sunk into, or in the same plane as the bubble sheet. The observer's response consisted of a value (1-5) rating the circle's distance from the front surface of the bubble sheet (Figure 5). A mark (+ or -) was recorded on the data sheet to indicate the perceived position of the circle in relation to the sheet (+ indicated the circle appeared to be in front of the bubble sheet; - indicated the circle appeared to be sunk into the bubble sheet). A rating of 5 indicated the circle was very far away from the bubble sheet and a rating of 1 indicated that the circle was not very far from the bubble sheet. A rating of zero (0) indicated the circle appeared to be in the same plane as the bubble sheet.

The observer first viewed the display binocularly while the display was static, translated and rotated. The observer then viewed the display monocularly while the display was static, translated and then rotated. The observer repeated

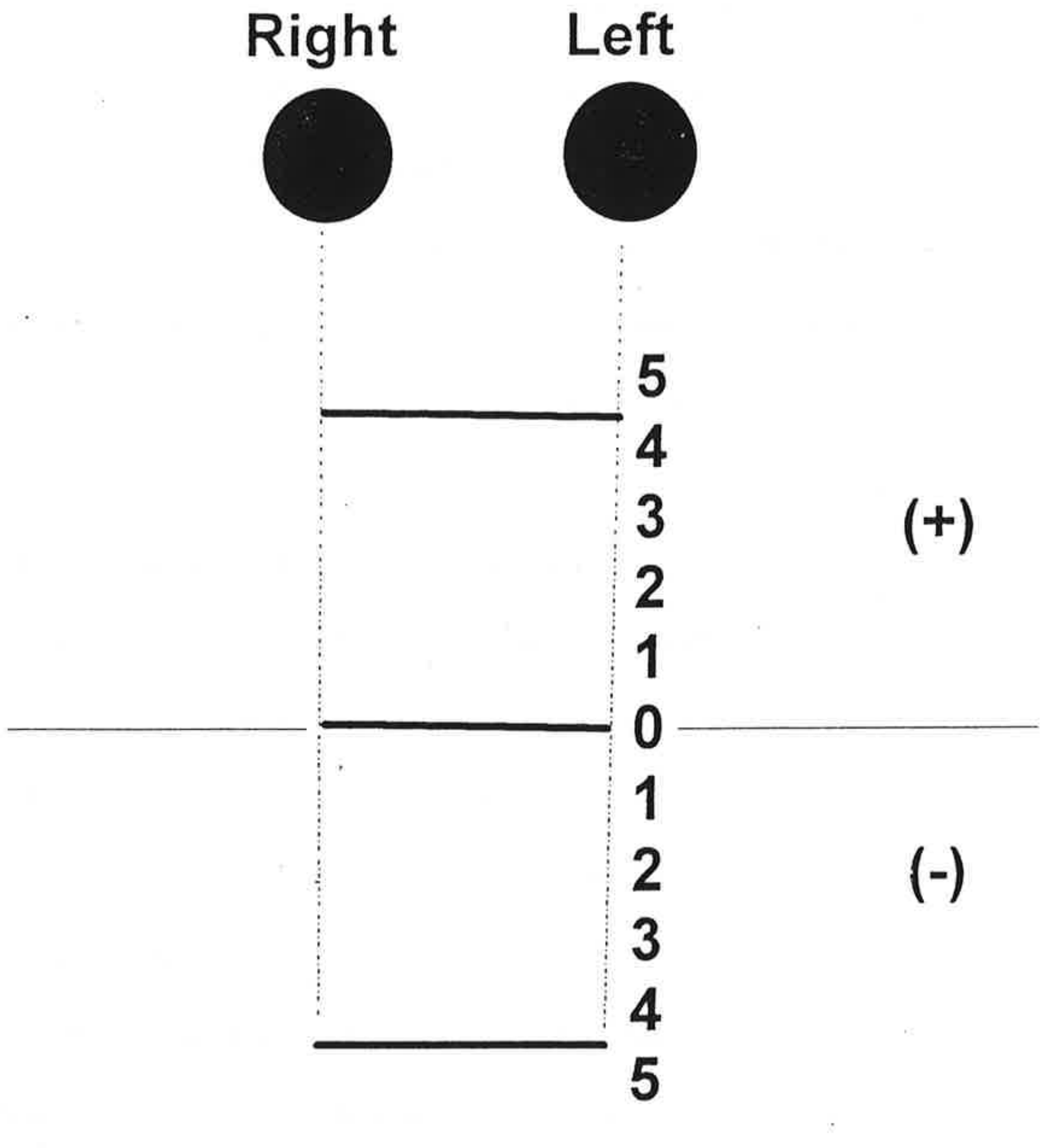

Figure 5. Rating scale for the illusion of depth observed in each display.

this sequence three times.

The binocular then monocular sequence of viewing the display allowed the observer to rest their eyes to prevent possible retinal suppression or after images from affecting the next viewing of the display. Pilot observers sometimes reported having difficulty in seeing the binocular depth effect. Retinal suppression may have occurred because one eye was not used during monocular viewing. When the observer then viewed the display binocularly, the disparate image may still have been suppressed for the eye not used during monocular viewing. Altering the viewing trials and allowing the observer to rest both eyes before continuing in the experiment would minimize suppression effects. Afterimages were reported by a few pilot observers because they were not instructed to blink their eyes while viewing the display. A change in the instructions was made in which observers were told to blink their eyes while viewing the display.

The procedure resulted in a 2 (monocular vs. binocular viewing conditions) X 3 (static, translating, or rotating movement conditions) X 3 (distances of 35, 50 or 65 cm) factorial design with repeated measures over viewing conditions and movement conditions. All observers viewed the same display. Observer's responses were recorded on a standard data sheet (Appendix C). Testing of each observer took approximately 25 minutes.

Results

An overall mean rating was calculated across the three trials for each test condition for each observer. Group mean ratings for each viewing distance were then calculated (see Figure 6). ANOVA indicated (Table 2) that there were significant main effects of monocular vs. binocular viewing conditions ($F[1,15]=34.752$, $p<.001$), and for the movement conditions ($F[2,30]=58.308$, $p<.001$). There was also a significant interaction between binocular/monocular viewing and movement conditions ($F[2,30]=25.213$, $p<.001$). Distance had no effect on judgments ($F<1.00$). Thus, the results supported the occlusion-disocclusion hypotheses for the observed visual illusion of depth.

Discussion

Observers consistently reported that the circle appeared to be sunk into the bubble sheet when viewed binocularly, but even with, or floating above, the bubble sheet when viewed monocularly. Moving displays produced depth impressions, too. Monocularly, translating or rotating the display yielded stronger impressions that the circle was in front of the bubble sheet. Motion interacted with monocular and binocular viewing: depth effects were generally more pronounced with motion, but in opposite directions (floating for monocular viewing, sunk in for binocular viewing).

What explains these results? By looking at the possible predictions (Table

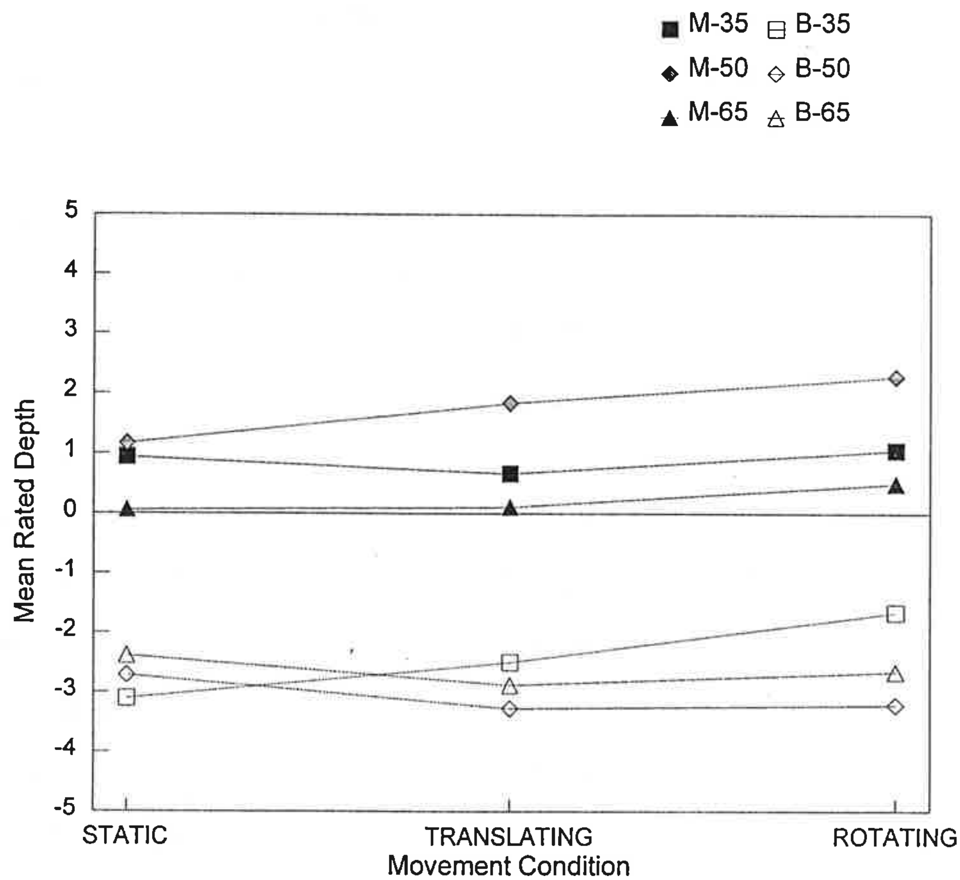

Figure 6. Mean ratings for the observed depth of the circle and the bubble sheet for each viewing condition in Experiment 1.

Table 2

Analysis of Variance for Experiment 1

Source	df	F	p
		Between Subjects	
distance	2	0.709	0.508
error	15	(4.398)	
		Within Subjects	
movement	2	58.308	0.001
error	30	(1.897)	
movement X distance	4	2.475	0.066
error	30	(1.897)	
mono/bino	1	34.752	0.001
error	15.	(1.055)	
mono/bino X distance	2	0.663	0.530
error	15	(1.055)	
movement X mono/bino	2	25.213	0.001
error	30	(2.719)	
movement X distance			
X mono/bino	4	0.889	0.482
error	30	(2.719)	

Note. Values enclosed in parentheses represent mean square errors (mono=monocular vision; bino=binocular vision).

1) one can see that the only explanation that could predict the primary effect observed--the circle sunk into the bubble sheet--is binocular GOLD. The results are consistent only with that geometry. GOLD occurs because each eye is able to see more of the bubble-like background texture at the contralateral edge of the circle than the other eye. As a result, the circle appears to be recessed into the bubble sheet.

For each binocular trial with the display, GOLD is in opposition with another explanation for the depth effect. During static viewing of the display, interposition is in opposition with GOLD. Translation and rotation of the display puts progressive occlusion-disocclusion in opposition with GOLD. Interposition and progressive occlusion -disocclusion disparity would produce an illusion of the circle floating above the background, but GOLD would produce an illusion of sunk-in depth. The result is that GOLD effects overwhelm both the progressive occlusion-disocclusion and interposition effects, and thus the circle looks sunk into the bubble sheet.

As explained earlier, any depth effect based on retinal disparity should vary with distance from the eye to the display, yet the results indicate that distance had no effect on judgment. The most likely explanation for this is that the distances chosen for this experiment were simply not greatly enough different to produce an effect. Distance may still yield some effect of depth, but not for the ones used here.

This research provided evidence that both a monocular and binocular illusion can be achieved through the same bubble sheet display. The experiment indicated that GOLD reasonably accounted for the depth effects observed in the bookmark illusion. The question was raised if GOLD could be present in other displays from the one used here. If so, could predictions be made about what observers would report?

EXPERIMENT 2

Experiment 1 showed that GOLD is a reasonable explanation for the set of monocular and binocular depth effects seen in the bookmark illusion. The peculiar optics of the bubble sheet apparently provides additional texture to the eye contralateral to an opaque occluding contour. If that is the case then it should be true that when a region of the bubble sheet is enclosed by opaque occluding contours, the extra texture available to the eye contralateral to that contour should yield the impression of a bulge in the bubble sheet. That is, the bubble sheet should appear to mound up out of an opaque circle. This is the effect tested in Experiment 2.

Distance had no significant effect in the results obtained from the previous experiment and so was held constant in this study. All observers viewed the display from the middle distance of 50 cm. Comments made by the observers following Experiment 1 raised the question of retinal suppression and after images occurring between monocular and binocular viewing of the display. It is known that binocular depth effects may take some time to become apparent, for example in viewing random dot stereograms (Julesz, 1986) or "Magic Eye" displays. So viewing time was introduced in Experiment 2 as a variable.

Method

Participants. Twenty-two observers volunteered from the Pembroke State University campus to participate in this study. The observers were screened for normal visual acuity (uncorrected or corrected by eye glasses) by a series of questions pertaining to their vision and visual skills as in Experiment 1. Due to the viewing arrangements in the apparatus used in this experiment, two observers were dropped from this study because they were unable to see the display clearly while wearing bifocal lenses. Thus, 20 observers were systematically assigned to one of two groups as they arrived to participate.

Equipment and materials. The same viewing apparatus was used as in Experiment 1, except the viewing display was modified. Observers all viewed a 25 X 25 cm bubble sheet covered with black opaque gummed paper. A hole centered on the black opaque gummed paper showed a 6 cm circular region of the bubble sheet. The display was hung in the viewing apparatus as in Experiment 1, at a distance of 50 cm from the observer's eye.

Procedure. Observers were placed into two groups to test to see if length of time viewing the apparatus would have an effect on observer's judgments or ratings. Individuals in Group 1 were labeled as a "free-response" group since they were allowed to give their judgments as soon as they liked. Individuals in group two were in a "timed" group and were instructed to look at the display for a full

30 sec before they gave their judgments or ratings. The observers viewed the display first binocularly then monocularly while the sheet was static, translated and rotated (in that order) by the experimenter. Observers judged whether the bubble sheet appeared to be in front of, sunk into, or in the same plane as the black surface around it. The observer's response was rated using the same 1-5 value scale as in Experiment 1 (Figure 5). A rating of 5 indicated the bubble sheet was very far away from the black surface around it. A rating of 1 indicated that the bubble sheet was not very far from the black surface around it. A rating of zero (0) indicated the bubble sheet and the black surface appeared to be in the same plane.

The procedure resulted in a 2 (monocular vs. binocular viewing conditions) X 3 (static, translating, or rotating movement conditions) X 2 (groups: free response vs. 30 sec timed) factorial design. All observers viewed the same display. Each observer received three trials on each of the six treatment conditions in the same presentation order as used in Experiment 1. Observers responses were recorded on a standard data sheet (Appendix D). Testing of each observer took approximately 25 minutes.

Results

An overall mean rating was calculated across the three trials for each test condition for each observer in both groups. Group mean ratings are shown in

Figure 7. ANOVA (Table 3) indicated that there were significant main effects of viewing conditions ($F[1,18]=23.867$, $p<.001$), and of the movement conditions ($F[2,36]=24.350$, $p<.001$) but not for groups. There was also a significant interaction between monocular/binocular viewing and groups ($F[1,18]=4.711$, $p=.044$). The results of the experiment indicated that observers consistently reported that the circle appeared to be bulging out of the black opaque surface for the binocular viewing condition. This is consistent with the hypothesis and again supports the GOLD explanation for the bookmark illusion. GOLD is present when the bubble sheet is seen within enclosing contours. The results of this experiment also indicated that viewing time alone, within the limits tested, had no effect on observers judgments.

Discussion

Observers consistently reported that the translucent circle appeared to be "bulging-out" of the black opaque surface around it for binocular, but not monocular, viewing of the display. This is consistent with predictions from the GOLD explanation.

It is important to note that the “bulging” illusion itself is a new illusion, predicted for the first time by GOLD. GOLD shows more of the bubble-like texture of the bubble sheet at the edge of it and the black surface. As a result, the circle appears to be “bulging-out” towards the observer for binocular vision.

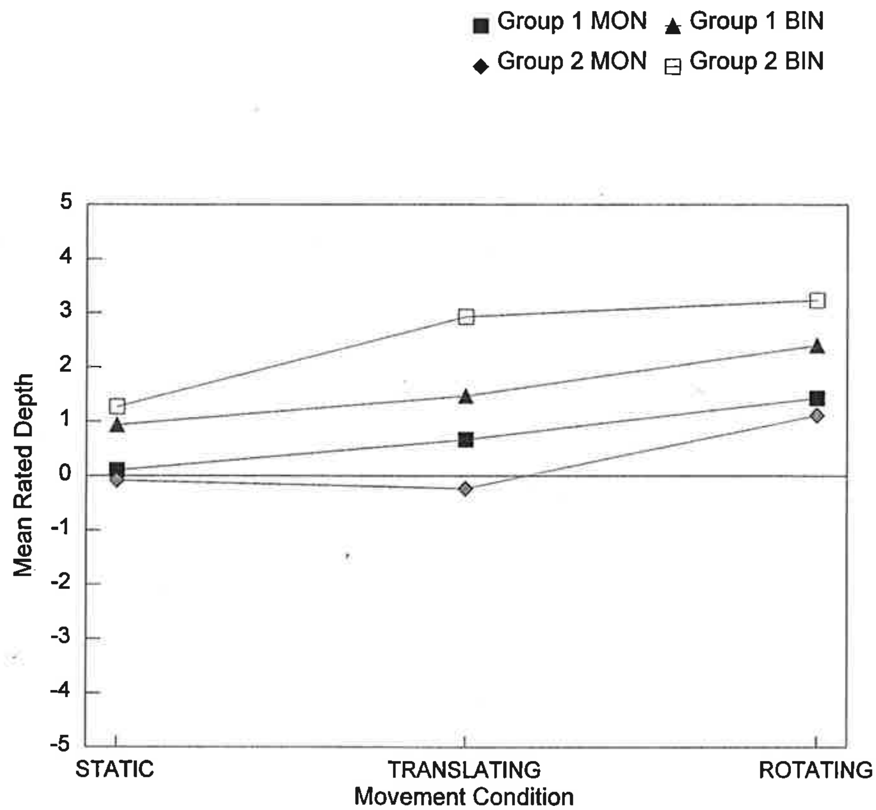

Figure 7. Mean ratings for the observed depth of the bubble sheet surrounded by an opaque black surface, for each viewing condition, in Experiment 2.

Table 3

Analysis of Variance for Experiment 2

Source	df	F	p
	Between Subjects		
group	1	0.415	0.528
error	18	(2.479)	
	Within Subjects		
mono/bino	1	23.867	0.001
mono/bino X group	1	4.711	0.044
error	18	(3.060)	
movement	2	24.350	0.001
movement X group	2	1.412	0.257
error	36	(1.380)	
mono/bino X movement	2	0.815	0.451
mono/bino X movement X group	2	1.182	0.318
error	36	(1.802)	

Note. Values enclosed in parentheses represent mean square errors (mono=monocular vision; bino=binocular vision).

When the display is viewed monocularly, no texture disparity occurs and the circle should appear to be seen as being even with or slightly behind the black opaque surface.

Observers in the free response group apparently saw the circle to be bulging out of the black opaque surface for monocular viewing of the display for all three movement conditions (Figure 7), and individuals in the timed response group reported seeing the display as bulging out of the black opaque surface for the rotating condition. The statistical reliability of this apparent effect was not demonstrated, but the data gives a hint that additional study of monocular effects is warranted.

The previous two experiments offer reasonably persuasive evidence that the bookmark illusion is the result of binocular GOLD produced by the unusual optics of the bubble sheet. The third experiment tested an additional prediction based on this principle.

EXPERIMENT 3

Since all explanations for binocular depth require horizontal disparity of retinal images (a left-to-right difference in theposition of images on the two retinas), displays that are most vertically oriented should produce the most pronounced depth effects. Vertical disparity of retinal images (up-down retinal position differences) should show very little depth. Anderson and Nakayama (1994) list contour orientation as another element of binocular depth perception. Any non-horizontal stripe can show a little binocular disparity. But the disparity should be more pronounced and clearer as the stripe becomes more nearly vertical. The greater the horizontal retinal disparity, the greater should be the resulting depth impression. The clearest disparity should be found when the contours are vertical. When contours are at an angle, the depth impressions should be weaker.

The display used in this experiment consisted of a stripe, displaced from horizontal by various angles, attached to the same bubble sheet used in Experiments 1 and 2. The main prediction was that observers would report seeing the stripe as having a greater effect of depth as it approached vertical and a lesser effect of depth at angles closer to horizontal. Viewing distance was held constant, and the variable of time was also manipulated.

Method

Participants. Forty-one volunteers participated in this experiment. All observers were screened as in Experiments 1 and 2 for normal visual functioning; two observers showed some visual deficit and were tested, but data was not used for further analysis. One observer voluntarily withdrew from participation, and four observers were used as pilots observers; thus 34 observers were assigned to four different groups (Group 1, n=9; Group 2, n=8; Group 3, n=9; Group 4, n=8).

Equipment and materials. Observers all viewed a display consisting of a 2.5 cm wide black opaque stripe adhered to the same kind of bubble sheet used in Experiments 1 and 2. The viewing assembly consisted of three pieces sandwiched together. The display was mounted on a circular sheet of plexiglas (approximately 30 cm diameter). This was attached to a 25 X 25 cm clear piece of plexiglass, 50 cm from the observer in the same viewing box as used in Experiments 1 and 2. The circular plexiglass panel was mounted onto the rectangular plexiglass sheet by means of a pivot (around which the bubble sheet-plexiglass rotated) located 30 cm from the sides and 40 cm from the bottom of the box. A thumbscrew was attached to the rear of the pivot bolt that allowed the display to be rotated manually. Once mounted observers saw a rectangular mask (a beige panel), with a circular hole (30 cm in diameter) cut in it through which the bubble sheet could be seen. The display had a series of drilled stops that allowed the stripe to be viewed in a static position at eight different angles (0°, 22.5°, 45°, 66.5°, 90°, 112.5°, 135°, 157.5°) from horizontal.

Procedure. Observers judged whether the black stripe appeared to be in front of , behind, or in the same plane as the bubble sheet. Observers responded using the same rating scale as in Experiments 1 and 2 (Figure 5). Observers responses were recorded on a standard data sheet (Appendix E and F).

Observers were assigned to one of four groups. Group 1 was a "free-response" group in which observers responded to the display as soon as they liked. Group 2 was a timed group, in which observers were instructed to look at the display for a full 15 sec before responding.

Group 3 was a "free response" group that was tested under a changed procedure (Appendix F) that included a different order in the presentation of angle 5 (90° from horizontal) during the first trial block. The reason for this procedural change (angle 5 was moved to the third position in the first trial block instead of the sixth) was that pilot observers were unable to observe any noticeable difference in the depth of the stripe, due to not seeing the most vertical orientation (angle 5) until almost the end of the first trial block. This change of procedure was implemented to see if the order in the presentation of angles in the first trial block would have an effect on observer's ratings.

Group 3 observers were also able to view and use the illustration of the rating scale (Figure 5) during experimentation to see what effect it would have on observer's judgment. Group 4 was a "timed" group that received the same changed procedure as Group 3.

The configuration resulted in a 2 (timed groups) X 2 (procedures) X 8 (angles) X 7 (trial blocks) repeated measures factorial design. All observers viewed the same display. Each observer viewed all eight angles in a randomized order in each of the seven trial blocks. Testing of each observer took approximately 45 minutes.

Results

An overall mean rating was calculated across the seven trials for each angle for each observer. Group mean ratings for each angle are shown in Figure 8. ANOVA (Table 4) showed significant main effects of group ($F[1,30]=24.848$, $p<.001$), and for the angles ($F[7, 210]=3.525$, $p<.001$) were found. A significant interaction between angle and trial block was found ($F[42,1260]=9.003$, $p<.001$).

The interaction associated with angles and trial blocks may be a result of "warm-up" or fatigue or both. There are two possible influences to account for warm up (getting used to the task and the range of angles); fatigue could have been due to the many judgments. ANOVA indicated that there was still a significant interaction for angle by block, $F(28,840)=8.415$, $p<.001$. The interaction apparently is a result of some other effect besides warm-up or fatigue.

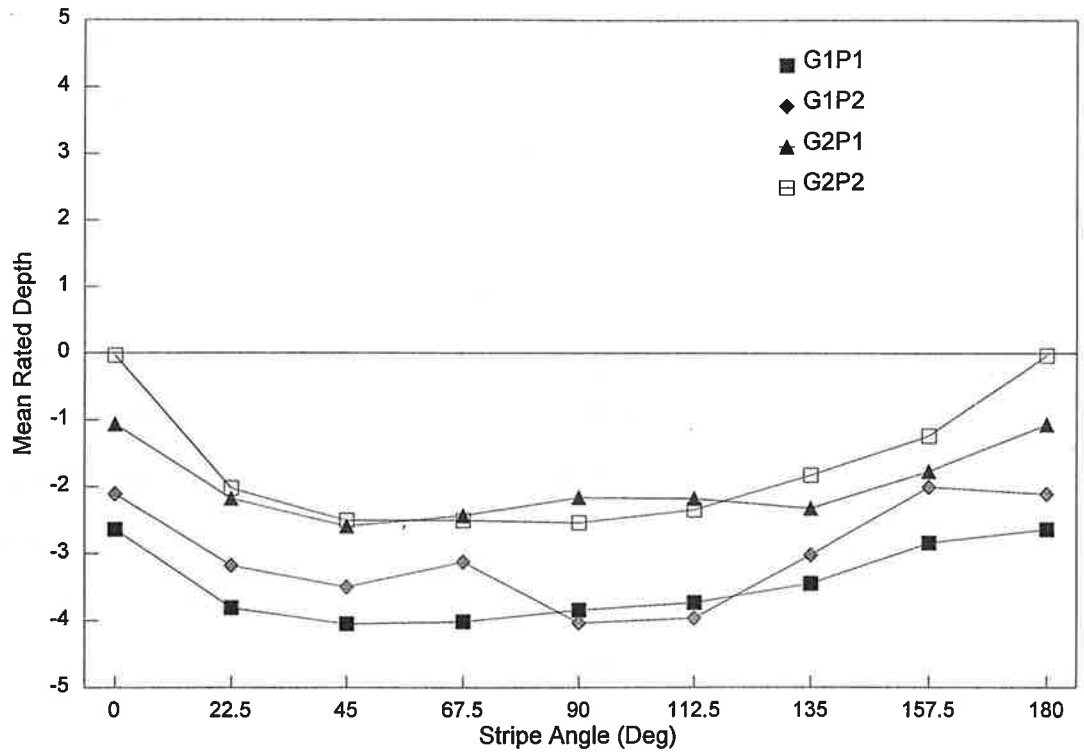

Figure 8. Mean ratings for the observed depth of the stripe for each viewing condition in Experiment 3. Note that the values plotted for 180° repeat the values plotted for 0°.

Table 4

Analysis of Variance for Experiment 3

Source	df	F	p
	Between Subjects		
group	1	24.848	0.001
procedure	1	1.273	0.268
group X procedure	1	0.226	0.638
error	30	(34.021)	
	Within Subjects		
angle	7	3.525	0.001
angle X group	7	0.696	0.675
angle X procedure	7	0.997	0.434
angle X group			
X procedure	7	0.531	0.811
error	210	(3.802)	
block	6	0.383	0.889
block X group	6	1.022	0.412
block X procedure	6	0.628	0.707
block X group			
X procedure	6	1.356	0.235
error	180	(1.878)	
angle X block	42	9.003	0.001

Table 4 (continued)

Analysis of Variance for Experiment 3

Source	df	F	p
angle X block			
X group	42	0.696	0.675
angle X block			
X procedure	42	0.997	0.434
angle X block X group			
X procedure	42	0.531	0.811
error	1260	(2.004)	

Note. Values enclosed in parentheses represent mean square errors.

Discussion

The results from this experiment showed that observer's judgments for the sunk into appearance decreased or increased in relation to the angle of the observed stripe, as predicted. As the stripe's physical angle increased from horizontal, the observer's judgments for the sunk into effect increased. As the stripe angle changed from vertical toward the horizontal, the sunk into effect decreased.

The results of this experiment indicated that horizontal disparity of retinal images, as occurs when viewing a stripe at various angles, can produce differences in depth in the bookmark illusion. One design factor that may interact with observer's judgment is the orientation of the stripe and orientation of the optical bubbles on the plastic sheet when the stripe is first mounted. The contour effect at the edge of the stripe may in fact be different when the stripe is adhered to the bubble sheet at a different relative angle than the one used here. Additional studies could address this.

It is a puzzle why observers tended to report the stripe as sunk into the bubble sheet even at the horizontal orientation of the stripe. The intention in this experiment was to have the most apparent contours in the display be those of the stripe. The stripe, however, extended across the beige panel and the ends of the stripe were occluded from the observer by the contours of the beige panel. There was no way to control where the observer looked at the stripe to judge its apparent depth. So, different kinds of interactions between the bubble sheet and display contours could have been present in different regions of the display. Greater impressions of depth could have occurred in the middle of the stripe than at the occluded edges of the stripe and the plastic sheet because more bubble sheet texture would be available to the eyes. If the observer consistently looked at the ends of the stripe where they met the circular opening, a smaller effect of depth (opposite the one predicted) might have been observed.

This experiment provided another means to demonstrate the GOLD effect in the bookmark illusion. All three experimental studies provided new information about this intriguing illusion, based on recently developed theoretical explanations of binocular depth perception.

GENERAL DISCUSSION

These are an important studies for several reasons. Although depth perception has been studied for hundreds of years, new approaches to understanding binocular depth perception are still being discovered (Barrand, 1979; Anderson & Nakayama, 1994; Anderson & Julesz, 1995). The three experimental studies applied these emerging theories of binocular depth perception in a new and unique way. The discussion of these findings includes a review of the optical effects of the translucent bubble sheet, major significant findings of each study, and possible extended applications of this research.

The "bubble sheet" used in these studies is responsible for the effect of depth observed. The "bubbles" appear as tiny optical ovals. These ovals are not physically present but are visible as a result of light reflecting off, and transmitted through the plastic sheet. The sheet is described by the manufacturer as embossed with tiny parabolic lens on both surfaces. The lens are positioned so that the interactions of reflected and transmitted light produce the optical bubble texture. No other information was available about the plastic sheet or the "bubbles" from the manufacturer. It is not clear, however, how the optics of the sheet produce the GOLD effect, though it is clear that this phenomenon occurs.

The results of these experiments provided data for binocular depth in a way not apparently previously known. The results of Experiment 1 showed that

GOLD explained the observable phenomenon of an object being sunk into the bubble sheet. No other explanation for binocular depth (classical stereopsis, static interposition, or progressive occlusion-disocclusion) predicted such an effect. GOLD predicted the binocular primary effect observed, the circle sunk into the bubble sheet. The results are consistent only with that geometry as illustrated in Figure 4. GOLD occurs because each eye is able to see more texture at the opposite (contralateral) edge of the circle and bubble sheet than the other eye.

Any binocular disparity effect should depend on viewing distance. The greater the distance, the smaller the binocular retinal disparity. The smaller the disparity, the less apparent any resulting depth effect. The distances used in this Experiment 1 were nonconclusive, but possible distance effects may still need to be investigated.

The translating and rotating movement of the display used in Experiment 1 may need further analysis. The supporting rod used to manipulate the display was controlled by the experimenter. No attempt was made to control movement speed, but since the manipulation of the rod was conducted by the same experimenter for all movement conditions for all observers, translation and rotation were fairly constant. Further evidence may suggest an effect movement rate could have on observers' judgments of the depth effect.

The results of this experiment led to a further analysis of the GOLD explanation.

Experiment 2 presented a new illusion never previously observed, but predicted by the GOLD explanation. The effect, an illusion consisting of the bubble sheet in the form of a circle bulging out of the surface around it, was observed. The optics of the bubble sheet allows more texture to be seen at the contralateral edge of an opaque sheet. As a result, the circle seems to “bulge” out towards the observer. The study also explored the effect of viewing time on rating the apparent depth of the display. Some binocular effects of depth take more time to become apparent than others. Time (free response vs. 30 sec) was only significant as an interaction between monocular and binocular viewing. No explanation for this effect can be offered. The length of time for each group was arbitrarily chosen. A more precise explanation of time effects on depth impressions needs to be investigated beyond what has been introduced here. Again, the same manipulation for translation and rotation of the display occurred as in Experiment 1. An effect of display movement for these conditions still needs to be further investigated.

Experiment 3 tested an additional principle of the GOLD hypothesis. The study showed that reducing horizontal disparity of retinal images reduces the effect of depth in the bookmark illusion. The results indicated observers consistently reported seeing a stripe appear more in depth at angles closer to vertical and less in depth at angles closer to horizontal. Contour orientation (stripe angle) was an effective element of binocular depth phenomenon. All viewing was binocular, and observers never reported the stripe as floating or even with the display. Further, at all angles, including horizontal, observers tended to report the stripe as sunk into the bubble sheet. This was a surprise and is a puzzle the present studies do not explain. Additional investigation is needed to analyze this result since the horizontal orientation of the stripe should have produced the least effect of binocular disparity and GOLD, and thus a floating or even with the surface depth effect should have been reported. As described earlier, effects of the edge of the circular frame surrounding the bubble sheet may at least partly account for this outcome.

These studies have introduced new displays that may help to understand the GOLD explanation and binocular depth effects in a unique illusion. This research also has several practical applications. This research has significant potential to provide a device that may be useful in explaining these emerging hypotheses on binocular depth perception. There is also a possibility that this object could be used to test for normal vs. abnormal binocular vision. Subsequent studies are planned to test other theories and elements of binocular depth effects using the unusual illusion described here.

The results of these experiments helped explain how the object studied works, tested predictions of new theories of binocular vision, and expanded our understanding of binocular depth perception. Since classical stereopsis can't provide an explanation for all binocular depth perception we must continue to seek new and additional theories of binocular depth perception.

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APPENDIX A

Pembroke
State
University
OF THE UNIVERSITY OF NORTH CAROLINA

Department of Education
One University Drive
Pembroke, NC 28372-1510
(910) 521-6221

MEMORANDUM

TO: Dr. Patrick Cabe, Department of Psychology

FROM: Donald R. Little, Chairman
Institutional Review Board for Research Involving Human Subjects

DATE: January 31, 1995

RE: Expedited Review of Research Proposal

Your research proposal entitled "Evaluation of an Unusual Binocular Depth Illusion" has been received and reviewed. It has been determined that the proposal research involves no more than minimal risk to subjects, therefore your request for an expedited review has been granted.

The review was completed in accordance with the provision for expedited review found in PL 93-348, Code of Federal Regulation (CFR) Title 45, Part 46, Subpart A, Section 46-110.

I am happy to report that your research proposal has been approved as submitted.

APPENDIX B

INFORMED CONSENT FORM
Bookmark Depth Illusion (BOOKMARK3)
Fall, 1995

I understand that the purpose of this research is to investigate human subjects' ability to judge depth in a visual pattern using one or both eyes, under several different movement conditions. I understand that the procedures involve looking at such patterns and reporting what I see in order to assess my ability to make such judgments. I understand that I may be asked for some personal information, such as age, gender, and any visual problems. I understand that the test session will take approximately one-half hour, and that the investigators believe that the study is of sufficient scientific merit to justify both their time and effort and that of myself and others.

Although a student assistant may work directly with me in this experiment, I understand that Dr. Patrick Cabe is the principal investigator responsible for the overall design and conduct of this study. Dr. Cabe agrees to be available to discuss my experience in this study with me, and, at the completion of the entire study, to explain the outcomes and interpretation of the investigation. I understand, however, that it may be some time after my own participation before complete information about the entire study can be made available.

I understand that none of the procedures planned in this experiment is intended to be painful or to produce discomfort; that they produce no known physical or psychological harm; and that I should expect no pain, discomfort, or harm from the procedures to be used.

I understand that any personal information collected from or about me will be kept confidential and that only group, or anonymous individual, data will be used and reported.

I understand that I am free to refuse to participate in any procedure and to refuse to answer any question at any time without prejudice to me. I understand that I am free to withdraw my consent and to withdraw from participation in the study at any time without prejudice to me.

I understand that by completing the research session described above I may receive credit toward course requirements in a psychology course offered by the Department of Psychology at Pembroke State University. On completion of the session, Dr. Cabe will report my participation to the instructor I specify. The amount of credit to be received is to be determined by my course instructor.

I understand that my consent to participate in this research does not waive any of my legal rights.

Having read and comprehended the above statement, I hereby agree to participate as a volunteer in the scientific investigation described in the foregoing statement.

____
Subject's name (please print)

______________________________ _______________
Subject's signature Date

= =

______________________________ _________________________
Instructor to whom participation should be reported Course number and title

APPENDIX C

SYSTAT CASE NO: __________

DATA SHEET

"An analysis of an unusual binocular illusion"
(BOOKMARK I, SPRING '95)

OBSERVER ________________________________ **OBSERVER #**_________
SEX M F **AGE** ________
DATE_______________

1.	Do you wear glasses?	YES	NO
2.	Do you wear bifocals or trifocals?	YES (B T)	NO
3.	Do you now suffer from or ever had crossed eyes?	YES	NO
	If yes, which eye? R L BOTH		
4.	Do you now suffer from or ever had a lazy eye?	YES	NO
	If yes, which eye?		
5.	Have you ever failed a motor vehicle eye exam?	YES	NO
6.	Do you have difficulty in seeing hidden 3-D "Magic Eye" posters?	YES	NO
	If yes, did you only have difficulty in seeing them the first time?	YES	NO

BINOCULAR VISION

	STATIC	TRANSLATION	ROTATION
TRIAL 1	_____	_____	_____
TRIAL 2	_____	_____	_____
TRIAL 3	_____	_____	_____

MONOCULAR VISION

	STATIC	TRANSLATION	ROTATION
TRIAL 1	_____	_____	_____
TRIAL 2	_____	_____	_____
TRIAL 3	_____	_____	_____

EYE used for monocular vision: RIGHT LEFT

APPENDIX D

SYSTAT CASE NO: __________

DATA SHEET

"An analysis of an unusual binocular illusion"
(BOOKMARK II, SUMMER '95)

OBSERVER ______________________________ **OBSERVER #**__________
SEX **M** **F** **AGE** ________
DATE________________

1.	Do you wear glasses?	YES		NO
2.	Do you wear bifocals or trifocals?	YES	(B T)	NO
3.	Do you now suffer from or ever had crossed eyes?	YES		NO
	If yes, which eye? R L BOTH			
4.	Do you now suffer from or ever had a lazy eye?	YES		NO
	If yes, which eye?			
5.	Have you ever failed a motor vehicle eye exam?	YES		NO
6.	Do you have difficulty in seeing hidden 3-D "Magic Eye" posters?		YES	NO
	If yes, did you only have difficulty in seeing them the first time?		YES	NO

BINOCULAR VISION

	STATIC	TRANSLATION	ROTATION
TRIAL 1	_____	_____	_____
TRIAL 2	_____	_____	_____
TRIAL 3	_____	_____	_____

MONOCULAR VISION

	STATIC	TRANSLATION	ROTATION
TRIAL 1	_____	_____	_____
TRIAL 2	_____	_____	_____
TRIAL 3	_____	_____	_____

EYE used for monocular vision: **RIGHT** **LEFT**

APPENDIX E

SYSTAT CASE NO: __________

DATA SHEET
"An analysis of an unusual binocular illusion"
(BOOKMARK III , FALL '95)

OBSERVER ________________________________ **OBSERVER#**___________

TIME/GRP: _____ **SEX : M F** **AGE** ____ **DATE**_______________

PROC: 1

1.	Do you wear glasses?	YES	NO
2.	Do you wear bifocals or trifocals?	YES (B T)	NO
3.	Do you now suffer from or ever had crossed eyes? If yes, which eye? R L BOTH	YES	NO
4.	Do you now suffer from or ever had a lazy eye? If yes, which eye?	YES	NO
5.	Have you ever failed a motor vehicle eye exam?	YES	NO
6.	Do you have difficulty in seeing hidden 3-D "Magic Eye" posters?	YES	NO
	If yes, did you only have difficulty in seeing them the first time?	YES	NO

BINOCULAR VISION

1. 4 ______	17. 2 ______	33. 8 ______	49. 2 ______
2. 2 ______	18. 8 ______	34. 6 ______	50. 7 ______
3. 6 ______	19. 5 ______	35. 3 ______	51. 3 ______
4. 7 ______	20. 3 ______	36. 5 ______	52. 5 ______
5. 8 ______	21. 1 ______	37. 2 ______	53. 8 ______
6. 5 ______	22. 7 ______	38. 4 ______	54. 6 ______
7. 1 ______	23. 4 ______	39. 1 ______	55. 4 ______
8. 3 ______	24. 6 ______	40. 7 ______	56. 1 ______
9. 5 ______	25. 8 ______	41. 5 ______	
10. 2 ______	26. 2 ______	42. 1 ______	
11. 7 ______	27. 7 ______	43. 7 ______	
12. 3 ______	28. 6 ______	44. 8 ______	
13. 8 ______	29. 3 ______	45. 4 ______	
14. 1 ______	30. 5 ______	46. 3 ______	
15. 4 ______	31. 1 ______	47. 2 ______	
16. 6 ______	32. 4 ______	48. 6 ______	

APPENDIX F

SYSTAT CASE NO: ________

DATA SHEET
"An analysis of an unusual binocular illusion"
(BOOKMARK III , FALL '95)

OBSERVER ______________________________ OBSERVER#__________

TIME/GRP: ____ SEX : M F AGE ____ DATE______________
PROC: 2

1.	Do you wear glasses?	YES		NO
2.	Do you wear bifocals or trifocals?	YES	(B T)	NO
3.	Do you now suffer from or ever had crossed eyes?	YES		NO
	If yes, which eye? R L BOTH			
4.	Do you now suffer from or ever had a lazy eye?		YES	NO
	If yes, which eye?			
5.	Have you ever failed a motor vehicle eye exam?		YES	NO
6.	Do you have difficulty in seeing hidden 3-D "Magic Eye" posters?		YES	NO
	If yes, did you only have difficulty in seeing them the first time?		YES	NO

BINOCULAR VISION

1. 4 ______	17. 2 ______	33. 8 ______	49. 2 ______
2. 2 ______	18. 8 ______	34. 6 ______	50. 7 ______
3. 5 ______	19. 5 ______	35. 3 ______	51. 3 ______
4. 7 ______	20. 3 ______	36. 5 ______	52. 5 ______
5. 8 ______	21. 1 ______	37. 2 ______	53. 8 ______
6. 6 ______	22. 7 ______	38. 4 ______	54. 6 ______
7. 1 ______	23. 4 ______	39. 1 ______	55. 4 ______
8. 3 ______	24. 6 ______	40. 7 ______	56. 1 ______
9. 5 ______	25. 8 ______	41. 5 ______	
10. 2 ______	26. 2 ______	42. 1 ______	
11. 7 ______	27. 7 ______	43. 7 ______	
12. 3 ______	28. 6 ______	44. 8 ______	
13. 8 ______	29. 3 ______	45. 4 ______	
14. 1 ______	30. 5 ______	46. 3 ______	
15. 4 ______	31. 1 ______	47. 2 ______	
16. 6 ______	32. 4 ______	48. 6 ______	

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