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Pulfrich Effect under Monocular Viewing[1]

Introduction - Classical Pulfrich Phanomenon

When a swinging ball target in the frontal-parallel plane is viewed with an attenuating filter over the left eye (see Figure 1), the target appears to rotate clockwise displaced in depth on an elliptical trajectory. This so-called Pulfrich phenomenon (Pulfrich, 1922, 558) has been explained by assuming that the target in the filtered left eye is processed with a longer latency than the unfiltered target in the right eye, thus causing a depth effect in the fused image (e.g., Lit 1949; Rock & Fox 1949; Wilson & Anstis 1969; Rogers & Anstis, 1972; Rogers, Steinbach & Ono (1974); Morgan 1977; Wake 1984, 1985; Wolpert, Miall, et al., 1993; Howard & Rogers 1995, 2002; Sekuler & Blake 2002; Kitaoka & Ashida, 2007). However, we found that no binocular fusion was necessary for the Pulfrich phenomenon.

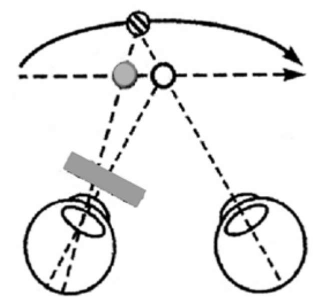

Fig. 1: Classical binocular Pulfrich.

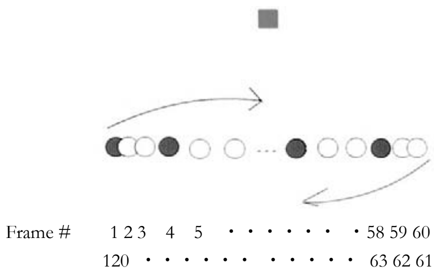

Fig. 2: Our monocular Pulfrich.

[1] Dedicated to Prof. Walter H. Ehrenstein, who passed away in January 2009.

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Experiment 1 - Pulfrich Phenomenon Under Monocular Viewing

We examined whether we could perceive any depth in the sinusoidally moving target under monocular viewing. If we could perceive any depth, it is clear that binocular fusion could not be a necessary condition for the Pulflich phenomenon. See Figure 2. We presented a white and a gray (not black as shown in Figure 2) disc in succession. The subject fixated her/his one (usually right) eye at the red (not gray as shown in Figure 2) fixation square, below which a flickering (between white and gray) disc target appeared to move along an elliptical path clearly displaced in depth.

METHOD

General Apparatus

We presented our stimulus patterns (a white disc and a gray disc) on a 19 inch computer display (Eizo, FlexScan1921), and controlled these patterns with a computer (Power Macintosh, 7100/80AV) and software (Micromind Director, version 5). A flickering (between white and gray) disc target oscillated horizontally to and fro within a range of 6 degree (or 40 mm on the display) with sinusoidal motion at 1/4 Hz. The flickering target appeared to move smoothly enough when 120 frames (30 frames/sec) were prepared for one cycle (see Figure 3). When the observer fixated her/his right eye on the fixation square and observed this oscillating target in her/his peripheral vision, this target appeared to move along an elliptical path displaced in depth. The observation distance was set ca.70 cm.

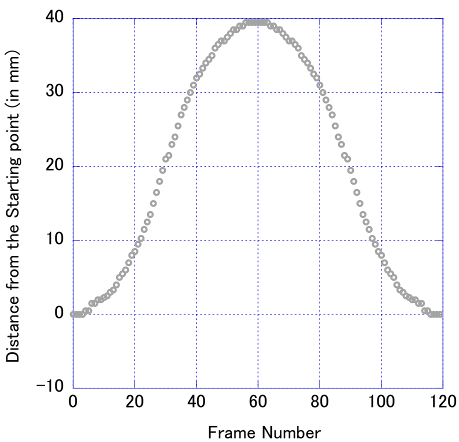

Fig. 3: Sinusoidal Motion (1/30 sec for every frame, or 4Hz motion).

An incandescent light from the ceiling (97 lux on the table, measured by an illuminometer Minolta, CL-100) provided a diffuse, ambient illumination of the room.

Subjects: 7 subjects (2 male students from the introductory course, 3 female graduate students, 1 male senior colleague, and 1 male this senior author) took part in this experiment. 5 students were not informed of the purpose of this experiment. All participants had normal or corrected-to-normal visual acuity.

Stimulus Condition: The targets were a pair of white disc and gray disc (diameter of 3mm) or a pair of white disc and white triangle of similar size, presented on a black BG(background). We added this latter condition to examine the effect of binocular fusion on the Pulfrich phenomenon; i.e., the depth might appear different between these two pairs when the fusion between white disc and white triangle was harder than that between white disc and gray disc. The gray disc target or the white triangle target was presented at various frequencies; i.e., once for every 20 frames (0.67 Hz), for every 12 frames (2.5 Hz), for every 8 frames (3.75 Hz), for every 4 frames (7.5 Hz), or for every 2 frames (15 Hz).

The optical property of each stimulus pattern was measured by a luminometer (Minolta, LS100). Black BG, 0.7 cd/m^2; gray disc, 6.53 cd/m^2; white disc, 19.05 cd/m^2; red fixation square, 3.36 cd/m^2, (x=o.635, y=0.335).

Procedure: The subject observed the flickering (between a white disc and a gray disc, or between a white disc and a white triangle) target with his right eye on her/his lower vision field while keeping her/his gaze at the red fixation square. It was not very easy for a beginner to keep fixating her/his eye on this fixation square, and some subjects needed a few training trials. When s/he could find a stable elliptical path of the target displaced in depth, s/he chose the most similar ellipse sample shown in Figure 4, and reported the step number of this sample. S/he could report some intermediate step, for example "5.3", if s/he found that the given 10 steps were too coarse for her/him. The subject was allowed to repeat her/his matching trials a few times; and her/his *final* match was taken as the valid response. Some subjects began their matching from the low alternation frequency condition, and the other subjects in the reversed order.

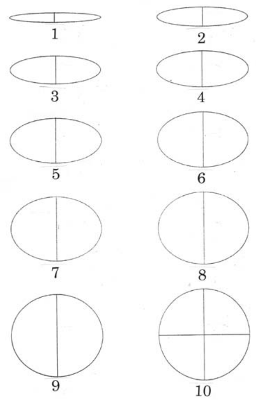

Fig. 4: The depth scale.

Results

The mean matching is shown in Figure 5. The subject clearly reported certain depth in the path regardless of the alternation frequency. Even in the rarest frequency condition of 0.67 Hz when the 2nd target (a gray disc, or a white triangle) was followed by the next 19 consecutive white discs, the depth appeared clearly enough.

The depths appeared rather similar for each frequency regardless in the pair of white and gray disc or in the other pair of white disc and white triangle. It is clear now that the fusion cannot be a critical condition for the subject to find the Pulfrich phenomenon.

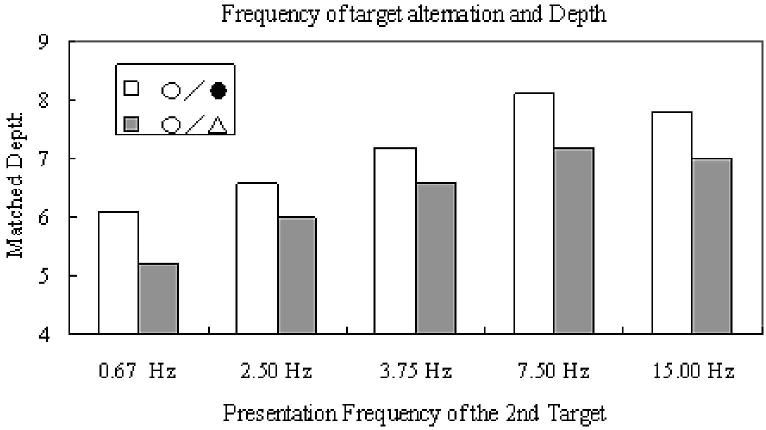

Fig. 5: The matched depth in Experiment 1.

These data were examined statistically by use of Anova (with repeated measures). The pair factor (white disc/gray disc vs white disc/white triangle) was significant ($F(1, 6)=7.84$, $p<0.005$). Thus the different brightness factor was more effective for depth perception than the different shape factor. The alternation frequency factor was also significant ($F(1,6)=33.82$, $p<0.002$). The depth appeared best at the 7.5 Hz condition, or when the 2nd target was presented once for every 4 frames. No interaction factors reached at significant level.

Discussion

In this Experiment 1 when two targets were presented successively to one eye, the subject reported clearly depth; i.e., one flickering target appeared to rotate along an elliptical trajectory displaced in depth. When the two different targets were moving along the same path, the visual system seemed to integrate them into one 3D trajectory. The amount of depth varied little, regardless of whether this 2nd target was similar or dissimilar to the 1st one, and whether the 2nd target was presented frequently or rarely.

How could we explain this depth perception? Perhaps the subject may extract two trajectories; i.e., one white disc trajectory and the other gray disc trajectory. When s/he can overlap these two trajectories, s/he may integrate them into a fused 3D trajectory displaced in depth.

Supplementary Experiment 1 - Two Control Conditions

In Experiment 1 above when two different targets were presented alternatively and successively on the same path, the subject reported one flickering target rotating along an elliptical path displaced in depth. When only one target was moving similarly as in Experiment 1, could the subject still find any depth in the trajectory? S/he observed this moving target under monocular viewing, similarly as in Experiment 1.

Subjects: 6 subjects (4 female students, 1 male senior colleague and this male senior author) took part in this supplementary experiment. The third student was not familiar with this kind of experiment. All participants had normal or corrected-to-normal visual acuity.

Stimulus condition 1: Every gray disc in Experiment 1 was replaced with a white one. The subject observed only a red static fixation square and an oscillating white disc target on a black BG.

Stimulus condition 2: Only a gray disc was presented in every 4^{th} frame.

Procedure: The subject fixated her/his right eye on the fixation square, and observed the moving target similarly to in Experiment 1. When s/he could find a stable elliptical path of the target displaced in depth, s/he matched the depth with the most similar ellipse sample in Figure 4, as in Experiment 1.
All subjects except the third one were well accustomed with this Experiment. All six subjects observed twice, and their 2^{nd} matching was taken as his/her result.

Results

Stimulus condition 1: The matched results in Stimulus Condition 1 are shown in Figure 6. The average matched depth was 2.5. Thus, the subject could find some depths, but apparently less than those found in Experiment 1.

Stimulus condition 2: The target only appeared once in 4 frames. The depth position of each target did not appear stable; i.e., sometimes slightly in front of and the other times slightly behind the display plane. No continuous path appeared, and we omitted to report these results.

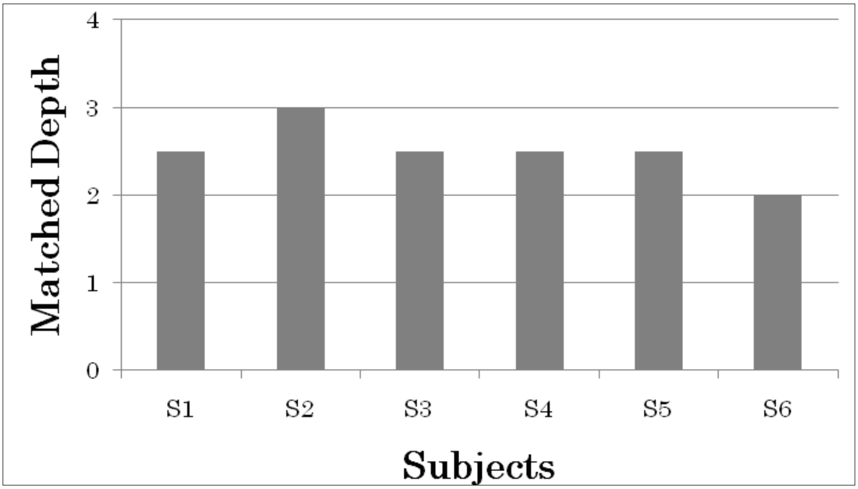

Fig. 6: The matched results in Control Condition 1.

Discussion

The depth perception of the moving target on the elliptical trajectory would have been promoted by the sinusoidal motion (i.e., slow at the both ends and fast in the center) in the horizontal path, but, the effect of this motion factor has rarely been examined.

The targets in our experiment were presented at 1/30th second intervals. The distance between the two neighboring targets was short at both the end-areas and long in the center area, so that the target moved slowly at the both ends and fast in the center.

Because the distance between the two targets in the path was varying so smoothly, the subject might hardly be aware of these changes. When the subject was less aware of the varying speeds, s/he could find only a shallow elliptical trajectory, but if s/he could be more aware of the various speeds of the target, s/he might find a deeper elliptical trajectory.

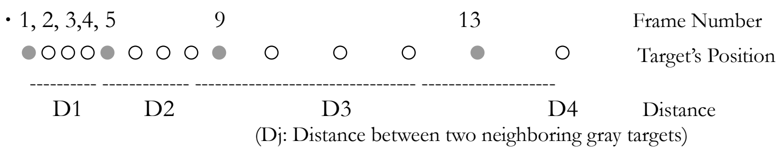

Fig. 7: Distance discrimination between gray targets.

Perhaps these gray targets might promote the depth appearance of the elliptical trajectory. Figure 7 showed that the distance between two neighboring discs (regardless of white disc or gray disc) changes quite smoothly. The subject may hardly be aware whether each of these distances was different from each other. However, when s/he attends to the gray discs, the subject may easily notice the distance variations between two neighboring gray discs, because the gray disc was presented not so frequently and the distance between this gray disc and the next gray disc varied much more broadly than the distance between any two neighboring discs. S/he might easily transform these different distances per unit period into 3D directed motions; i.e., s/he might transform short distances at both ends into the target's motion backwards or forwards, and long distances in the center into the target's motion in the frontoparallel plane. Then, the target might appear to move circularly at a constant speed in his/her imaginary 3D space.

We will add some training effects. In our supplementary experiment 1, Subject 3 was a beginner. At the 1st trial in the stimulus condition1, she reported an almost flat trajectory. In her 2nd trial, she found a slight depth and matched it with the scale depth value of "2.5". S/he should learn to observe carefully the moving target so that so that s/he might notice various speeds of the target. Without these careful observations, the target would appear to oscillate only on an almost flat plane.

Experiment 2 - Monocular vs Binocular Viewing

In the classical experiment (Pulfrich, 1922), binocular fusion is regarded as essential for the Pulfrich effect (see Figure 1) to appear. It is also well known that the bigger the luminance difference between the two discs becomes, the deeper the elliptical path of the target appears in depth. On the other hand, targets which are too different cannot appear to be fused. White targets never appear to be fused with black target. In this binocular viewing condition when the right eye picks up the white target trajectory and the left eye the gray target trajectory, these two discs might not appear to be fused, and still s/he might find a 3D trajectory. We have already reported in Experiment 1 that the subject under monocular viewing condition could find the target moving along a 3D elliptical trajectory with no fused image. We expect that the subject under binocular viewing condition could find similarly even with no fused image.

In Experiment 2, we used two line targets, instead of the two disc targets; i.e., a vertical white line bar to the left eye and a tilted white line bar to the right eye, so that we might easily change the degree of similarity between the two targets by changing the tilted angle of the latter bar, see Figure 9. Under the binocular viewing condition, the subject should fix her/his eyes on the red fixation square and could find a fused square. S/he might find a fused line target when these two lines were only slightly different. No fused target would appear when the latter tilted line tilted too much.

Under monocular viewing conditions, a line target oscillated to and fro flickering between vertical and tilted, and no fused image appeared. Under binocular viewing conditions, the targets appeared fused in the least different line pair, but they were not fused in the other pairs. Our concern was whether s/he could find any depth in the trajectory of these no fusion conditions.

Method

We presented the stimulus patterns on a computer display of 19 inches *(EizoFlexScan1921)*, and controlled the movements of these targets with a computer (Power Macintosh, 7100/80AV) and software (Macromind Director, version 5), similarly as in Experiment 1.

Binocular Viewing: One target for the left eye was a vertical line (15 mm in length, and 1 mm in width) and the other for the right eye an oblique (15, 35 or 70 deg. tilted from vertical, 15 mm in length, and 1 mm in width) line. These targets were oscillating in phase to and fro with sinusoidal motion at 1/4 Hz within a range of 6 degree. These targets needed 120 frames or 4 sec for one cycle (30 frames/sec) to move smoothly, as in Experiment 1. The subject observed these stimuli through a stereoscope (see Figure 8a).

In the condition of the vertical line for one eye and the least tilted (or, 15 deg from vertical) line for the other eye, the subject found a fused jutting line bar from behind to front, oscillating to and fro almost horizontally on the monitor display below the fused red fixation square. In the more tiled (i.e., 35 or 70 deg from vertical) line conditions, these two target lines appeared to overlap each other (✗) in 2D style.

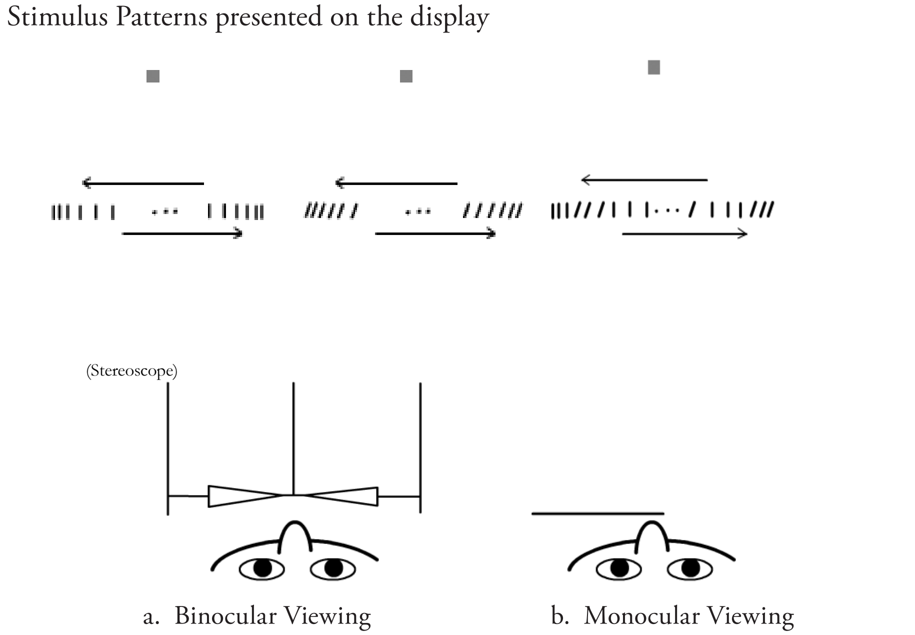

Fig. 8: Stimulus patterns and apparatus used in Experiment 2.

Monocular Viewing: See Figure 8b. One target was oscillating on the horizontal plane as in the binocular condition, but now the 1st line target was alternated with the 2nd tilted line target in every 3 consecutive frames (or 100 msec). When the subject fixated her/his one eye on the fixation square, the alternating targets appeared to rotate along an elliptical trajectory displaced in depth. S/he should match the depth of this elliptical trajectory with any one sample shown in Figure 4, similarly as s/he did in Exp. 1. No fused image was reported under monocular viewing condition.

Subjects: 5 subjects, the same members as in Experiment 1, took part in this experiment.

Results

The targets appeared to oscillate to and fro along an elliptical path displaced in depth, under binocular viewing conditions and similarly under monocular viewing conditions. The mean matched depth in each condition is shown in Figure 9. **Binocular Condition:** The target pair of vertical line and least tilted (15 deg from vertical) line appeared generally fused, and the subject perceived a 3D line bar, jutting out from left backward to right forward. This 3D bar oscillated horizontally between left and right on an almost flat frontoparallel plane. In the other two conditions, where more tilted line targets were contained, the pair appeared no more fused. The overlapped lines appeared in the 2D style (i.e., in the form of ✗), and the whole targets appeared to rotate along an elliptical path displaced in depth.

Monocular Condition: The line target appeared always fluctuating between vertical and tilted, and this fluctuating whole appeared to rotate along an elliptical path deeply displaced in depth.

Statistical Examination: These data were examined statistically using Anova with repeated measures by the use of SPSS. The binocular/monocular factor was significant ($F(1,4)=164.35$, $p<0.001$); the tilted angle factor (15, 35 or 70 deg from the vertical) was significant ($F(1,4)=122.99$, $p<0.001$); and the interaction between these factors (binocular/monocular x tilted angle) was also significant ($F(1,4)=55.19$, $p<0.002$).

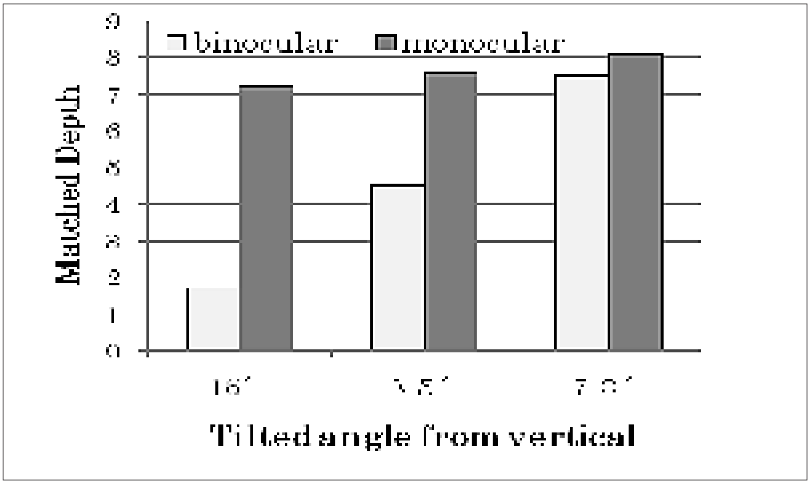

Fig. 9: Matched depth in Experiment 2.

Discussion

The Role of Binocular Fusion: We discussed previously (Taya, Ohashi & Ehrenstein 2008) that binocular fusion prevented the Pulfrich effect. In this Experiment, also, the binocularly fused target in the least tilted (15 deg) condition appeared to move almost flat on the screen plane (see Figure 9).

Monocular vision: The target appeared always fluctuating, and this fluctuating whole appeared to rotate along an elliptical path, deeply displaced in depth, regardless of any angle of the tilted target line. The eye system seemed to extract two quite similar but somewhat different paths, and seemed to integrate these two paths into one 3D path, just as the binocular system integrates two different binocular images into one 3D image. The eye system seems to work similarly whether the two successively presented targets may be different not only in the brightness dimension (white or gray disc), but also in the shape dimension (disc or triangle), or in the orientation dimension (vertical or oblique line). The depth appears similarly in any different properties.

Binocular vs Monocular: When the two slightly different targets appear fused in the binocular viewing, this fused target appears to oscillate only flat on the display screen. On the other hand, the not fused whole appeared to oscillate displaced in depth. When the subject observes successively the same pair under monocular viewing, a fluctuating target appears to rotate along a deep elliptical path. In our daily life, the binocular images are generally slightly different from each other, and this binocular system should be very good at keeping a plane at a definite depth. The monocular system appears to be good at extracting slight differences between the successively presented images, thus the subject might find the relative depth more clearly under monocular viewing rather than under binocular viewing.

Supplementary Experiment 2

Extraction of one 3D Path under Binocular Viewing

When we look at a moving object, we usually get a pair of slightly different moving binocular images. However, when we binocularly look at a pair of the same moving images with no binocular disparity, could we still find an object moving along a path in the depth dimension? We propose now that an essential condition for the depth perception would be the two different target images rather than the binocular disparity. We showed next a control experiment on the depth effect comparing the effect of two different targets with the effect of two identical targets.The subject observed a pair of moving targets binocularly with no binocular disparity; i.e., a pair consisting of a white disc and a gray disc (the different targets condition), or a pair of the same white disc targets (the same targets condition). S/he observed these targets under the next 3 presentation conditions.

Different Condition: **(a) Continuous**: In every frame, a white disc target was presented for the left eye and a gray disc was for the right eye. **(b) Alternation with one blank frame:** In the left eye, the white disc was presented in every 1st frame, blank in every 2nd frame, the white disc in every 3rd frame, blank in every 4th frame, and so on. In the right eye, blank in every 1st frame, the gray disc was presented in every 2nd frame, blank in every 3rd frame, the gray disc in every 4th, and so on. **(c) Alternation with 3 blank frames**: In the left eye, the white disc was presented in every 1st , 2nd , and 3rd frame, blank in every 4th, 5th , 6th frame, and so on. In the right eye, blank in every 1st , 2nd , and 3rd frame, the gray disc in every 4th, 5th , 6th frame, and so on.

Same Condition: All gray discs in the above conditions were replaced with white discs.

Subjects: 4 subjects (3 female graduate students and 1 male senior author) took part in this experiment. All members had already participated in the previous Experiment 2. These 3 students were not informed on the purpose of this experiment. S/he could repeat her/his trials a few times until s/he could well be satisfied with her/his own responses. Her/His final responses were adopted as her/his results.

Results

In the different pair condition of white target and gray target

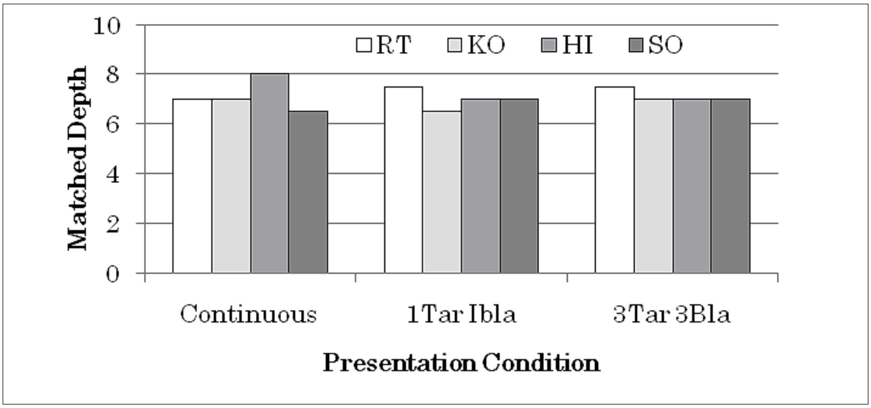

Fig. 10: Matched depths in Supplementary Experiment 2.
The 3 items on the x-axis correspond with 3 stimulus presentation conditions; i.e., continuous, alternation 1 target with 1 blank frame, and alternation 3 targets frames with 3 blank frames.

The matched depths in Supplementary Experiment 2 are shown in Figure 10. When two targets were different from each other, the subject always detected good depths. However, when the same white discs were presented, the subject could hardly detect depth. No one reported greater depths than 3.0 in the depth scale. We omitted to report these results on the same white discs condition.

Discussion

The classical Pulfrich phenomenon has been explained as a trajectory of the binocularly fused targets. When the presented targets were two identical white discs, these two discs would fuse easily, but then the subject could report almost no depth. Thus, essential for the depth perception seems to be the presentation condition of two different targets.

The depth appeared similarly in any of our 3 different presentation conditions. In the last two (i.e., 1Tar 1Bla, and 3Tar 3Bla) conditions, no mating between the white and the gray disc was possible, but even then depth was always reported.

Thus the eye system, whether it might be a monocular or binocular system, seems to extract two different trajectories from two different target series to integrate them into one 3D trajectory.

Experiment 3 - On Johannson's (1975) "invisible rod"

We might explain our monocular depth vision after Johansson (1975), who presented two moving targets of the same color. The two targets were tracing an ellipse in the opposite direction from an imaginary center point. His subject always found a wheeling invisible rigid rod, of which only the two end points were visible. His "perceptual tendency toward abstract projective invariance" is quite strong and is verified easily. When we presented two moving targets with a certain frame distance between them in our Experiment, our subject could also extract a rigid rod.

We presented two moving discs. The 1st disc target was always followed by the 2nd disc target with a few frames distance. In the case of 3 frames distance, for example, when the 1st target was presented at the 5th frame, the 2nd target was presented at the 8th frame. The physical distance between these two targets became wider in the center of our linear path, and narrower near both ends.

The subject could find a rigid rod between these two targets, though the physical distance between them was always changing. The subject should convert the rod of various lengths into a rod of constant length in the various depth directions. In our next Experiment, two different target pairs were presented with a constant frame distance (i.e., 1, 2, 3 or 5 frames distance) between them. In Condition WG(white-gray), the subject might find easily two different trajectories, but would hardly do them in Condition WW(white-white). S/he might find easily a rod of rigid length in condition WW, but could not do so easily in Condition WG. Then, we might discriminate the depth effect derived from the different trajectories from the depth effect of Johansson's rotating invisible rigid rod.

Method

Stimulus Conditions: A pair of discs (a pair consisting of a white disc and a gray disc, or the other pair consisting of a white disc and a white disc) were oscillating to and fro synchronously, similarly as before. The subject fixated his/her one (right) eye on the red fixation square. The gray used was the same one used in Experiment 1.

Condition WG: The 1st white disc was followed by the 2nd gray disc with 1, 2, 3 or 5 frames lag.

Condition WW: The 1st white disc was followed by the 2nd white disc with 1, 2, 3 or 5 frames lag.

Procedure: The subjects fixed her/his right eye on the fixation red square as in the previous experiments. S/he matched the apparent depth of elliptical trajectory with a depth sample shown in Figure 4. The measurement order was set at random. S/he could repeat his/her measurements a few times. Her/His final responses were adopted as her/his results.

Subjects: 2 female graduate students (KO & HI), and 1 male author (RT) took part in this experiment. All members had been well trained.

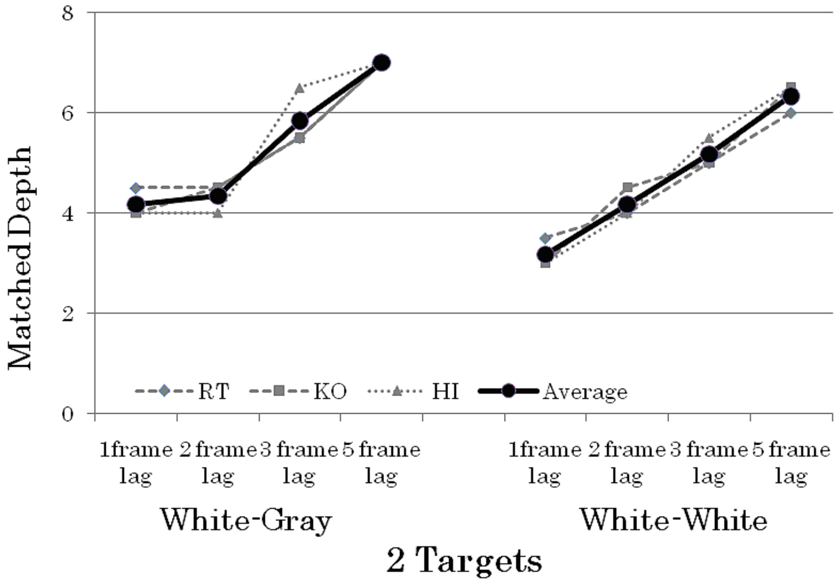

Fig. 11: Matched depths when 2 targets were simultaneously presented.

In Condition WG, the two different targets appeared to pass successively over the same elliptical path, but no rod between the two targets appeared. In Condition WW, the invisible rod between the two targets appeared clearly. The matched depths are plotted in Figure 11. We analyzed our data by ANOVA with repeated measurements.

Frame Distance: The more the two targets were separated from each other, the deeper elliptical trajectory appeared. The factor of Frame Distance (linear factor) was statistically significant ($F(1,2) = 117.27$, $p<0.01$).

WG pair vs WW pair: This pair factor was statistically significant ($F(1,2)=75.00$, $p<0.02$).

Discussion

1) The frame distance between the two targets: The wider the frame distance between the two targets was, the more outstandingly the depth of the elliptical trajectory appeared. The wider frame distance between the two targets varied more than the narrower frame distance did. The subject could transform the bigger variation to the deeper elliptical path.

2) WG pair vs WW pair: The elliptical path appeared deeper in WG pair than in WW pair condition. Thus, the subject might find depth from the 2 different targets overlapping on a same path rather than from an invisible rod rotating along an elliptical path.

General Discussions

The Mechanism of Depth Perception under Monocular Viewing

(1) Monocular Viewing and Binocular System
When our subject observed under monocular viewing, not only the corresponding monocular system but also some binocular system might work. Based on their motion aftereffect experiment, van Kruysbergen & de Weert (1993, 1994) proposed two binocular systems; i.e., 1) simple binocular system and 2) pure binocular system (see Figure 12).

Adapting one eye (e.g., the right eye) to a clockwise stimulus motion and testing with this same eye led to an anticlockwise motion aftereffect, as one might usually expect. Next, adapting the right eye to a clockwise stimulus motion and then testing the left eye led, again, to an anticlockwise motion; i.e., an inter-ocular transfer was observed. Some information should have been transmitted from the first adapting right eye through the binocular system to the tested left eye. This binocular system is called the "*simple binocular system*". This system is activated as soon as information arrives from either one of the eyes. On the other hand, the other "*pure binocular system*" is activated only when fusible information from both eyes reaches this system.

In our Experiments with monocular viewing condition, all information on each pair of targets should be transmitted to both the corresponding monocular system and the simple binocular system, where these two successively presented trajectories might be integrated, similarly to when s/he observes them binocularly. When the pair of targets could not be fused under binocular viewing, the information might also be transmitted to the same simple binocular system, when the two targets could not appear to be fused.

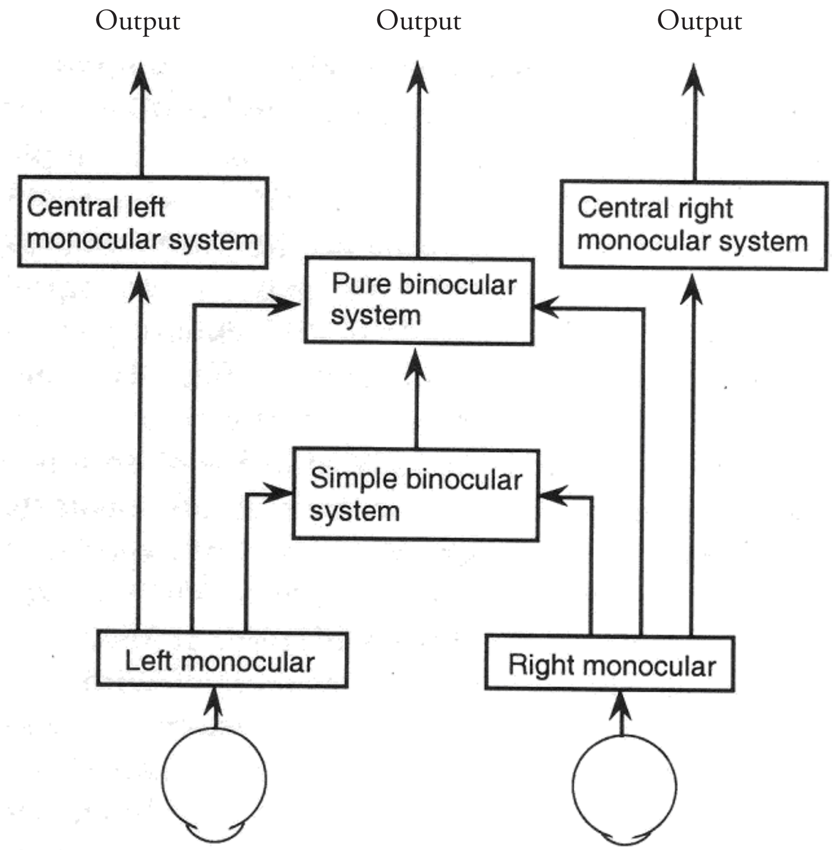

Fig. 12: The pooling theory by van Kruysbergen & de Weert (1993, 1994).

When the two targets under binocular viewing appeared well fused, i.e., when the pure binocular system seemed to be activated, this fused image should appear to oscillate to and fro only on an almost flat plane, as shown in our Figure 9 in the case of binocular viewing, the 15 deg condition. Good depths could appear only on the simple binocular system when the two targets could hardly be fused.

(2) Johansson's Projective Invariance (on Experiment 3)
When two moving spots were tracing an ellipse in the opposite direction, the subject saw that a tilted rigid rod is rotating in a plane (Johansson 1975). In spite of these various distances between these two spots, the observer could well abstract a certain projective invariant length. However, the subject in our Experiment 3 reported bigger depth in the different pair (WG) condition, when two trajectories from two different targets were overlapping to each other, than in the same pair (WW) condition when Johansson's invisible rod could easily appear. That is, Johansson (1975) would not help us much.

(3) Binocular Stereopsis Without Binocular Fusion

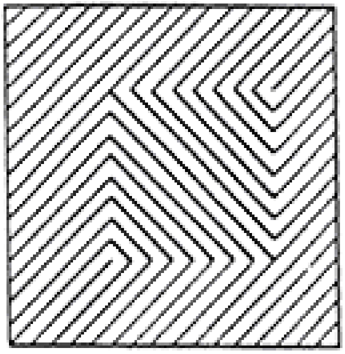

Image L (for the left eye)

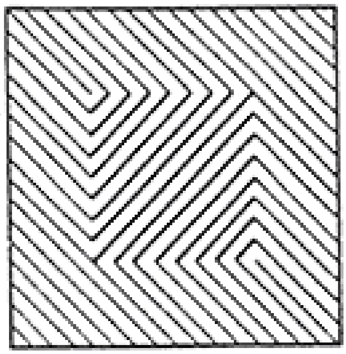

Image R (for the right eye)

Fig. 13: Kaufman's Stereogram (1974).

When one observes the patterns presented in Figure 11 (after Kaufman, 1974) through a stereoscope, an inner square clearly appears floating in front of a large background square, though every line in both squares is in a state of binocular rivalry. The simple binocular system can integrate two monocular images into one 3D image.

Howard & Rogers reported (1995, 314) that their two stimuli in rivalry formed a well combined percept when they were presented for less than 200 ms. In our Experiments, each stimulus pattern was presented only for 1/30 sec, stereopsis would be always possible.

Concluding Remarks

In the classical Pulfrich studies, the phenomenon was explained only when the two binocular images were fused. In our report, the phenomenon appeared when the two binocular images were not fused, and the well fused image appeared to move almost flat. The subject could find this phenomenon also under monocular viewing. The subject seems to abstract two different trajectories corresponding to these different targets, and should integrate them into one 3D trajectory in depth, which might be almost a creation occuring in the brain. Essential for depth perception seems to be two different discs, which were similarly oscillating on the identical path, and not each binocularly fused target.

Summary

The Pulfrich phenomenon, since the days of Pulfrich (1922), has been very frequently explained through connecting all theoretically fused images of binocular targets. We could observe this phenomenon also under monocular viewing (see Figure 2). Binocular fusion could not be necessary. It would not be critical for the subject to find depth whether s/he observes binocularly or monocularly. It seems to be certain that the depth cannot appear without two different targets (e.g., a white disc and a gray disc). The simple binocular system (see Figure 12) could accept any monocular/binocular images, and we speculate that this simple binocular system could integrate all these simultaneously/ successively presented different images into 3D system.

Keywords: monocular viewing, binocular viewing, two different targets, simple binocular system.

Zusammenfassung

Der Pulfrich Effekt wurde seit Pulfrichs Tagen (1922) sehr häufig durch die Verbindung aller theoretisch bei der beidäugigen Erfassung des Objekts miteinander verschmolzenen Seheindrücke der beiden Augen erklärt. Wir konnten dieses Phänomen jedoch auch bei einäugiger Betrachtung beobachten (siehe Abb. 2). Eine Verschmelzung im Zuge beidäugiger Betrachtung konnte also kei-ne notwendige Bedingung sein. Es wäre demnach für die Tiefenwahrnehmung nicht entscheidend, ob das Subjekt mit beiden Augen oder nur mit einem Auge schaut. Es scheint allerdings gesichert, dass die Tiefenwahrnehmung nicht ohne zwei unterschiedliche Zielobjekte im Wahrnehmungsfeld (z.B. eine weiße und eine graue Scheibe) auskommen kann. Das einfache binokulare System (siehe Abb. 12) konnte beliebige monokulare/binokulare Bilder akzeptieren, und wir vermuten, dass es alle diese gleichzeitig bzw. aufeinander folgend dargebotenen verschiedenen Bilder in ein dreidimensionales System integrieren könnte.

Schlüsselwörter: monokulares Sehen, binokulares Sehen, zwei unterschiedliche Zielobjekte, einfaches binokulares System.

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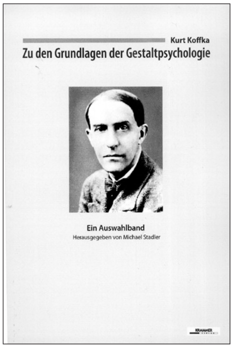

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Kurt Koffka (1886-1941) zählt mit Max Wertheimer und Wolfgang Köhler zu den Gründervätern der Gestalttheorie der Berliner Schule. 1935 erschien sein Hauptwerk „Principles of Gestalt Psychology", in dem die Gestaltpsychologie erstmalig systematisch dargestellt wurde, in englischer Sprache. Fragt man in den USA nach der Gestaltpsychologie, so werden die „Principles" auch heute noch fast immer einzig und allein genannt. Im deutschsprachigen Raum hingegen erlangte Koffkas Hauptwerk, da die „Principles" bis heute nie in deutscher Sprache veröffentlicht wurden, nie die Bekanntheit und Geltung, die ihm zustünde. Im nun vorliegenden Auswahlband erscheinen die ersten drei Kapitel dieses Klassikers der Gestaltpsychologie in deutscher Übersetzung. Abgerundet wird diese Einführung in die Grundlagen der Gestaltlehre durch einen Überblicksbeitrag Kurt Koffkas aus dem Jahr 1925 über die Psychologie und ihre Kernthemen aus der Sicht der Gestalttheorie – eine kritische Auseinandersetzung mit bis heute einflussreichen Grundannahmen in der Psychologie, die an Aktualität nichts eingebüßt hat. Leben und Werk Kurt Koffkas werden in ergänzenden Beiträgen des Herausgebers, Univ.-Prof. Michael Stadler (Universität Bremen), beleuchtet.