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Bachelor Liberal Arts and Sciences

Head and Eye Movement in Binocular Rivalry: a Virtual Reality Experiment

Bachelor thesis (7,5 ECTS)

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ABSTRACT

This virtual reality experiment was conducted in order to study the possible effects of vertical and horizontal head and/or eye movements on stimulus dominance in binocular rivalry. Studying movement effects in binocular rivalry with the use of virtual reality allows for gaining more knowledge about visual perception, this has not been done previously in this way. To gather data, 15 participants in this experiment individually took part in 4 virtual reality trials during which their perceived visual dominance of either horizontal or vertical lines was recorded over time. The recorded responses were then compared to the orientation of the stimulus. During this experiment it was determined that the dominance of either horizontal or vertical lines is not congruent with the orientation of the stimulus. Other possible effects are yet to be uncovered. This experiment demonstrates an experimental condition that is more ecologically validating for researching binocular rivalry than most research that has been conducted so far. Studying binocular rivalry and visual perception with the use of virtual reality is therefore highly desirable for future research.

INTRODUCTION

Binocular rivalry occurs when a distinctly different image is presented to each eye. Rather than fusing the visual information from both eyes together, our perception of the two images alternates. While the image presented to one eye dominates, the image from the other eye is suppressed. The dominance generally switches every few seconds resulting in perceptual alternations of the two presented images.

Binocular rivalry is a very interesting phenomenon for investigating visual perception. When binocular rivalry is experienced, the external stimulus remains unaffected while conscious visual perception alters. Expanding knowledge on this topic therefore contributes to understanding the neural processes underlying conscious visual perception. Learning more about binocular rivalry is also beneficial for progress in artificial intelligence research. When learning more about visual perception and how it works in humans, this knowledge can also contribute to research in visual reproduction by machines.

Generally, binocular rivalry is regarded as an automatic process but it can be influenced by a variety of conditions. During binocular rivalry the eyes compete for dominant perception. This dominance is never completely won by one of the eyes (Alais & Blake, 2005; Wheatstone, 1852). The stimuli seen by the eyes are also competing for dominance and this dominance is neither never completely won by one of the presented stimuli (Blake & Logothetis, 2002). In both cases, the dominance keeps alternating. However, effects have been found that influence the degree of dominance of a stimulus.

Whether a stimulus is more dominant depends on a few factors. Salience is one of the factors that decides which stimulus we perceive. A stimulus is for example particularly more noticeable when it has a high contrast, is bright or when it is moving rather than when it has a low contrast, is dim or when it is stationary (Fahle, 1982). A stimulus also dominates our perception when it is more recognisable to us (Yu & Blake, 1992). Attention plays a part as well, when voluntary attention is directed to a certain stimulus, this stimulus is less likely to be suppressed (Ooi & He, 1999).

Orientation of the stimulus is another factor that is important in the competition for dominance of the stimulus. When the eyes must choose between a vertical and a horizontal grating, the horizontal orientation seems to be rather “weak” and a vertical-effect is noticed in dominance (Fahle, 1982). A vertical grating dominates our perception significantly longer than a horizontal grating. This was found in conditions of static stimuli as well as moving stimuli (Wade, De Weert & Swanston, 1948).

Another finding is that certain eye movements (optokinetic nystagmus, OKN) can serve as cues for which stimulus will be dominant during a rivalry experiment (Enoksson, 1963). When presenting the left eye with a stimulus that is moving leftward and the right eye with a stimulus that is moving rightward, the eye movement will correspond to the perceived motion direction of the stimulus. The stimulus that is moving in the same direction as the direction of eye movement will be perceived as dominant in binocular rivalry (Hayashi & Tanifuji, 2012).

Most experiments in binocular rivalry so far are conducted using equipment that requires participants to remain stationary when presented with 2D stimuli. These methods may seem somewhat unrepresentative for our understanding of underlying mechanisms of our visual perception in our “real” 3D world. It often also limits the participants from moving their head and/or eyes which makes it unable to study potential effects. There is no data yet on the influence of moving the head and/or eyes in 3D surroundings while experiencing binocular rivalry. It is unknown what would happen with our visual perception if we were able to look at differently oriented stimuli in a dichotic presentation in a 3D world, while being able to move our head and/or eyes.

Traditional experimental apparatus do not allow to research this movement in experiments. Fortunately, the increased usage of virtual reality opens possibilities for researching possible movement effects on existing phenomena, like binocular rivalry. In an experiment, studying movement can add ecological validity to perceptual phenomena (Soranzo & Wilson, 2015). Virtual reality makes studying movement in binocular rivalry possible. In a virtually created 3D world, participants are able to move their head and eyes towards a certain stimuli while still experiencing binocular rivalry.

This paper attempts to find an answer to the following question: what is the effect of horizontal and vertical movement from the head and/or eyes on binocular rivalry when presented with distinctive oriented stimuli in a virtual reality experiment? As found in earlier research, the dominance of a moving stimulus will correspond to the direction of certain eye movements (Hayashi & Tanifuji, 2012). In the experiment described in this paper, perceived motion of horizontally and vertically orientated stimuli will compete for dominance and it could therefore be expected that when moving the head and/or eyes horizontally, the horizontal lines will be more dominant in our perception and when moving the head and/or eyes vertically, the vertical lines will be more dominant in our perception. Hence, the hypothesis states that visual perception will be dominated by the stimuli that is congruent with the direction of movement from the head and/or eyes.

METHODS

Participants

In this experiment, a total of 15 participants took part. The participants consisted of 8 women and 7 men, aged between 19 and 27 years. All participants studied at a University or a University of applied sciences in the Netherlands and they all spoke and understood the Dutch language. Every participant had either normal or corrected to normal stereoscopic vision.

Materials and Stimuli.

This experiment was constructed with the use of Unity and presented to the participants through HTC Vive virtual reality glasses. The HTC Vive was linked to a Windows computer and a monitor where the observer could follow the movement of the participant's head. The participant and the observer were seated in front of a desk on which the HTC Vive and the computer monitor were placed. In front of the participant, a keyboard was also placed on the desk through which the participant submitted his/her response. The stimuli were shown on a black background with either red vertical lines that were presented to the left eye or blue horizontal lines that were presented to the right eye.

Design

The experimental design that was used for this experiment is repeated measures within participants. The independent variables were the movement of either the eyes (E) or the movement of the head (H) and the direction of movement being either vertical (1) or horizontal (2). These independent variables were measured in 4 different conditions: 1E, 2E, 1H, 2H. The conditions were measured in a total of 4 trials, consisting of 2 head movement trials with vertical and horizontal movement and 2 eye movement trials with vertical and horizontal movement. All participants took part in each of these trials and were assigned the order of conditions randomly. A participant started either with two head movement trials or with two eye movement trials. Every trial lasted 300 seconds. During these trials for each eye the amount, width, luminance, colour, position and the distance between the lines were kept constant. The stimulus was also kept constant in size, colour, luminance, position and time between the change of positions. The stimulus was a dot appearing at different positions over time in the 3D surroundings of both eyes. The stimulus was presented on one of the following positions: middle, up, down, right, left. The stimulus would always start in the middle position, then appear in one of the other positions before it went back to the middle position. This process lasted 2,7 seconds. The measured dependent variable was the perception of dominance of either the red vertical lines or the blue horizontal lines during these 2,7 second trials.

Procedure

When the participant arrived, he or she was taken to the laboratory where they took place behind the desk. They signed the form of consent and after that were given the instructions for the tasks. The participants were instructed to do two things. Firstly, they were told that they had to look at the dot. When the dot switched position, the participant had to move, depending on the assigned trial, either her/his head or only her/his eyes towards the new position of the dot and look at the dot again. Participants were instructed to keep doing this until the trial was over. Secondly, the participants were instructed to use the right arrow key and the left arrow key on the keyboard. When they felt that more than 50% of what they saw was red vertical lines, the participants had to press and hold the left arrow key. When they felt that more than 50% of what they saw was blue horizontal lines, the participants had to press and hold the right arrow key. When switching between arrow keys the participants were instructed to release the previous key. Before starting the tasks, the participants were shown images that illustrated examples of what they might see during the trials. These images are shown below.

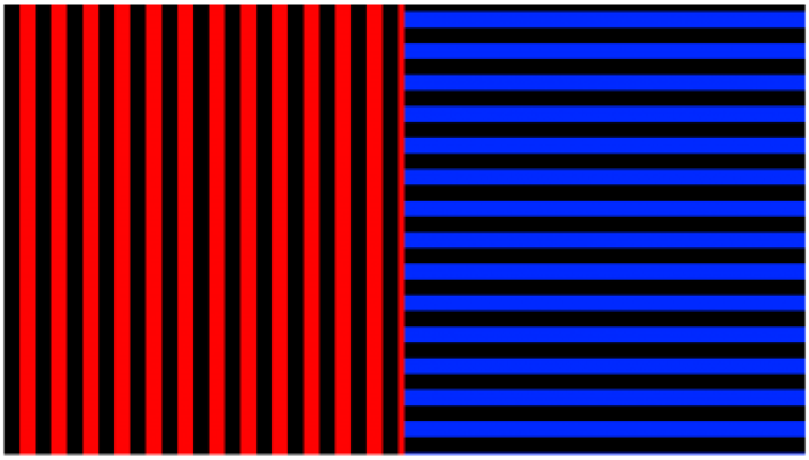

Figure 1: Example of possible equal dominance of red and blue lines during the tasks.

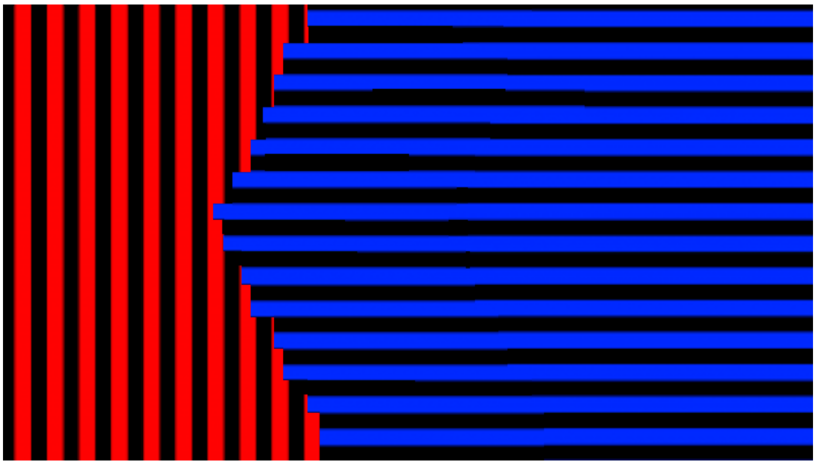

Figure 2: Example of possible dominance of blue lines during the tasks.

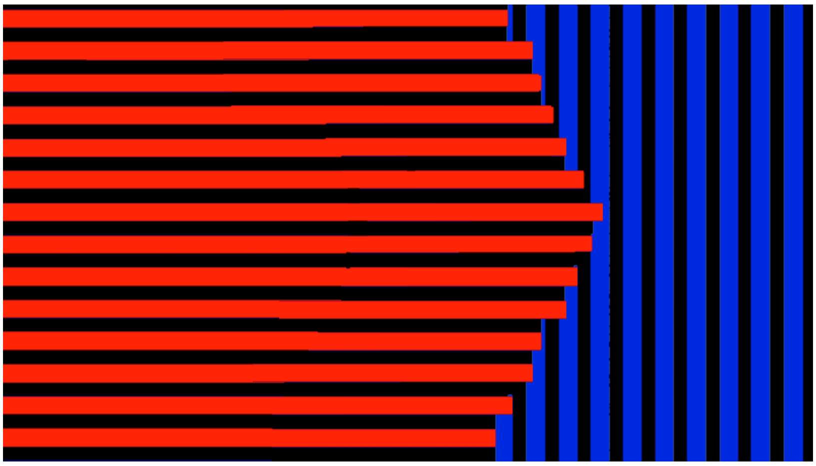

Figure 3: Example of possible dominance of red lines during the tasks

After the instructions, participants were assisted with putting on the HTC Vive and a small test trial was conducted. The test trial lasted about 20 seconds. After the test trial the participants started the main task. Before starting each trial, the participants were instructed whether to move their head or only their eyes. Between every trial the participants had a short break. When the trials ended, the participants were asked if they had any remarks about the experiment or their responses. Lastly, they were given the participation compensation, for which they had to sign a form stating they had received this compensation.

RESULTS

Eye movement tasks

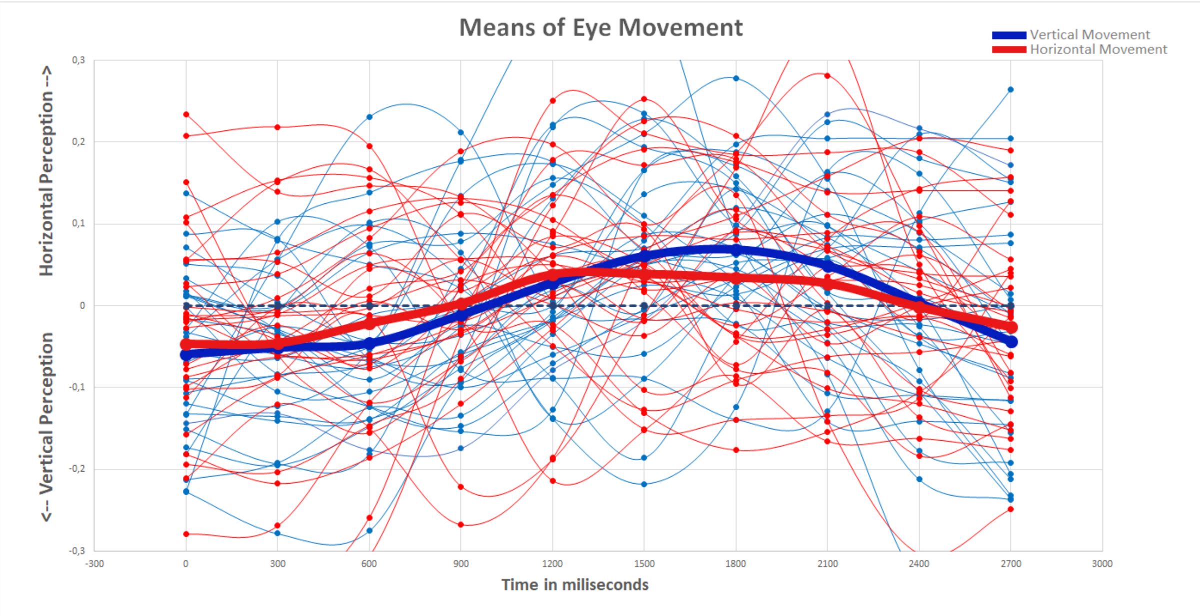

Figure 4: Every thin line depicts the means of a participant in one of the eye movement conditions, split up in vertical eye movement(blue) and horizontal eye movement(red). The thicker lines depict the overall mean for the two conditions.

The graph in figure 4 shows the measured means and the overall mean for the two conditions of the dominant perception during vertical and horizontal eye movement. The reported dominant perception seems to follow a certain trend for the horizontal movement as well as for the vertical movement. These trends look quite similar. The lines of both eye movement directions start with vertical perception at 0 milliseconds. After approximately 900 milliseconds, both lines switch to horizontal perception and at approximately 2400 milliseconds, both lines switch back to vertical perception. Another observation is that values of the means in the vertical movement have a broader range as the reported values of this movement are lower and higher than the values of the horizontal movement.

Head movement tasks

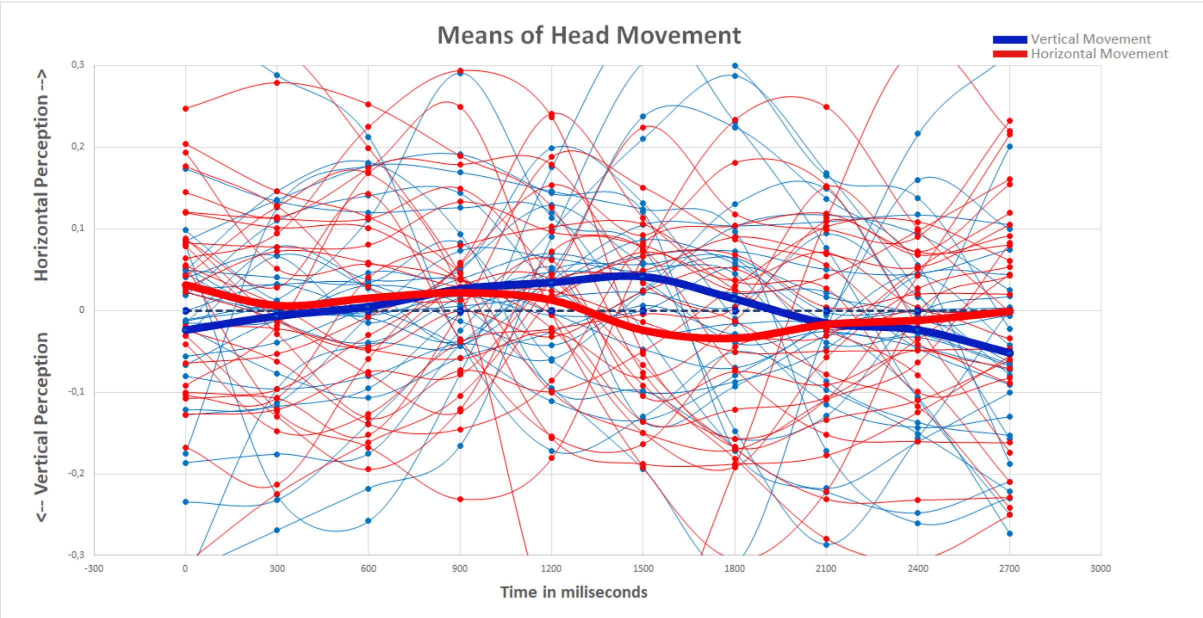

Figure 5: Every thin line depicts the means of a participant in one of the head movement conditions, split up in vertical head movement(blue) and horizontal head movement(red). The thicker lines depict the overall mean for the two conditions.

The graph in figure 5 shows the measured means and the overall mean for the two conditions of the dominant perception during vertical and horizontal head movement. The reported dominant perception again seems to follow a certain trend for the horizontal movement as well as for the vertical movement. This time the trends look somewhat similar but vertical and horizontal movement seems to operate in opposite directions. At 0 milliseconds the vertical movement line starts with vertical perception and the horizontal movement line starts with horizontal perception. The lines seem to follow a similar course between 300 and 900 milliseconds where they are both ascending towards horizontal perception. The vertical movement line then continues to ascend to its highest value at 1500 milliseconds, reporting horizontal perception, while the horizontal movement line descends to its lowest value at 1800 milliseconds, reporting vertical perception. The lines then cross each other again at approximately 2100 milliseconds, both reporting vertical perception. The vertical movement line then shows a delicate descend to vertical perception at 2700 milliseconds. The horizontal movement line shows a delicate ascend and ends just below horizontal perception at 2700 milliseconds.

Statistical analysis

The left table below shows the statistical scores for the measurements in the eye movement conditions. V1 refers to the mean of the first point of measurement (0 milliseconds) of the vertical eye movement. H1 refers to the first point of measurement (0 milliseconds) of the horizontal eye movement. V2 refers to the mean of the second point of measurement (300 milliseconds) of the vertical eye movement. H2 refers to the second point of measurement (300 milliseconds) of the horizontal eye movement. These results have been used in a paired t-test and were compared against a null hypothesis of V=H using the 95% interval confidence. As can be seen in the statistical analyses, no significant difference was found at any level of the paired t-test. Therefore, the null hypothesis can be accepted, indicating that when comparing the eye movement means V and H over points in time, these means are not significantly different.

The right table below shows the statistical scores for the measurements in the head movement conditions. These results have been used in a paired t-test and were compared against a null hypothesis of V=H using the 95% confidence interval. In the statistical scores it can be seen that a significant difference has been found for pair V1-H1: $t(29) = -2.10$, $p = .045$ and for pair V6-H6: $t(29) = 2.16$, $p = .039$. However, a lot of tests were done and the significant difference could as well be due to the cause of chance. Therefore, the null hypothesis can be accepted indicating that when comparing the head movement means V and H over points in time, these means are not significantly different.

PAIR	MEAN	STD. DEVIATION	SIG. (2-TAILED)
V1-H1	-0,01293	0,152016	0,645
V2-H2	-0,00565	0,144439	0,832
V3-H3	-0,02454	0,154175	0,39
V4-H4	-0,01368	0,146184	0,612
V5-H5	-0,00985	0,126725	0,673
V6-H6	0,022685	0,137189	0,373
V7-H7	0,034777	0,135629	0,171
V8-H8	0,022029	0,145863	0,415
V9-H9	0,005379	0,164237	0,859
V10-H10	-0,01822	0,15812	0,533

PAIR	MEAN	STD. DEVIATION	SIG. (2-TAILED
V1-H1	-0,05504	0,143712	0,045
V2-H2	-0,01279	0,156809	0,658
V3-H3	-0,01045	0,16437	0,73
V4-H4	0,00425	0,152922	0,88
V5-H5	0,021289	0,130649	0,379
V6-H6	0,065461	0,16586	0,039
V7-H7	0,048022	0,159749	0,11
V8-H8	0,001507	0,155045	0,958
V9-H9	-0,01156	0,1437	0,663
V10-H10	-0,0507	0,173599	0,121

Two more statistical tests were conducted. This time, the overall means of V1 to V10 and the overall means of H1 to H10 have been used in a paired t-test and compared against a null hypothesis of V=H using the 95% confidence interval. This has been done for both the eye movement condition and the head movement condition. No significant difference has been found for either movement condition. The null hypothesis can therefore be accepted for the eye movement condition as well as for the head movement condition. This indicates that the overall means for vertical and horizontal movement directions are not significantly different from one another, in both eye and head movement conditions.

DISCUSSION

The hypothesis for this experiment states that visual perception will be dominated by the stimuli that is congruent with the direction of movement from the head and/or eyes. With this hypothesis, it was expected that the vertical movement means over time would be significantly different from the horizontal movement means over time, because vertical movement would likely report mostly vertical dominance and horizontal movement would likely report mostly horizontal dominance. This was tested in the statistical analysis for both movement conditions. The results are not in favour of the hypothesis for this experiment. No significant difference between the means of vertical movement and horizontal movement in points over time has been found. The overall means of vertical and horizontal movement also turned out to not being significantly different. The dominance of vertical or horizontal lines is therefore not congruent with the direction of eye and/or head movement.

This experiment leaves us with the question if and what kind of effects the head and eye movements have on the dominant perception during binocular rivalry tests. Even though an effect was expected, the statistical tests that were conducted did not show evidence to back this up. However, future studies could look into other possible effects of (head and/or eye) movement as a contributing factor in binocular rivalry, by using virtual reality equipment. This experiment has showed that virtual reality is an effective tool for researching visual perception. The upcoming use of virtual reality can greatly contribute to these kinds of experiments and will add ecological validity to the experimental conditions, therefore allowing us to gain more knowledge on this topic.

An observation from this experiment is that in the eye movement condition, the vertical head movement seems to have a wider reach than the horizontal head movement. The vertical head movement might be somewhat “stronger” than the horizontal head movement. This could be due to the vertical effect that highlights the horizontal stimulus as being in a “weaker” position (Fahle, 1982). If the vertical stimulus has a stronger effect, maybe the vertical movement does as well. This could also explain that in the head movement condition, the vertical movement line seemed to be somewhat stronger because unlike the horizontal line it reached congruent dominance at the last mean measured. However, more research and statistical tests would be necessary in order to validate this observation.

An improvement for this experiment could be to make the trials of 300 seconds a little shorter. This because participants reported having trouble with seeing dominance in the last minute of the trials. Fatigue and loss of concentration could arguably have influenced the performance on perceiving or reporting dominance. Also, participants with corrected eyesight that were wearing contact lenses reported that they felt their eyes were very dry at the end of each trial and this was uncomfortable for most. This could arguably have influenced the performance on perceiving dominance as well. It could therefore be recommendable to only test participants with normal eyesight in future studies.

In conclusion, this experiment has showed that the orientation of the dominating stimuli in a binocular rivalry experiment is not congruent with either vertical or horizontal eye and/or head movement. It also shows us that virtual reality opens new doors in research and can be used in order to gain more information about visual perception. Gaining more information about the effect of (head and/or eye) movement in binocular rivalry, as well as in other visual perception phenomena, allows us to expand knowledge on this topic. Future studies looking for experimental conditions with high ecological validity can take into account the advantages of the use of virtual reality in visual perception research.

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