Out of Body Experiences: Multiple Sensory Replacement Experiments (March 2010)

Ben Cao, Joshua Clausman, Thinh Luong

Index Terms—**Sensory substitution, Self-consciousness, OBE**

I. MOTIVATION

OUT-of-body experiences (OBE) have been recorded by researchers and described as an experience that involves observing one self's physical body from a third person perspective. The causes of this phenomenon originated from disturbances to the normal brain functions, such as strokes, seizures, and drug abuses. Since then, researchers were able to reproduce OBE on healthy participants by using sensory replacement experiments. Vision and proprioceptive senses are the most studied for sensory replacement. It has been shown that multimodal sensory interaction creates a stronger effect in subjects in a wide variety of tests.

The results produced by the sensory replacement experiments benefit our understanding and approaches to developmental robotics. For example, sensory replacement experiments required some level of embodiment to be effective. Those experiments help researchers to explore the concepts behind self awareness: how do one distinguish oneself from his/her surroundings; self learning: how to make sense of one's environment from experiments or collected data; and self prediction: how to deduce an action that was never performed from a prior knowledge. The sensory replacement experiments can help in solving questions about the human developmental process and apply it to developmental robotics. Further more, what happens if audio sensory is introduced to the experiments? How would audio in combination with other senses affect the OBE felt by the participants?

We will be addressing three primary questions:

1. Can an out-of-body illusion be created using only visual and audio cues?
2. If a subject is allowed to move, will the illusion be stronger?
3. Do out-of-body illusions need to occur in a body which physically mirrors our own?

II. RESOURCE NEEDED

Four Experiments

1. Tap-test : reproduce experiment with visual proprioceptive stimulus
2. Audio-test : stationary head, walk around virtual head
3. Track-test : use head tracking to allow horizontal (1 degree freedom) movement
4. Separation-test : change eye/ear distance on virtual head and see how sensors are affected

Experiment one is to verify our setup is similar to past research. Experiments 2-4 are our novel approaches.

Material

All tests

- Two webcams
- Two microphones, with artificial ear
- HMD
- Noise cancelling earmuffs to go over headphones
- Stand/mount for virtual head
- Computer with two unused VGAs and VLC media player to run video to HMD

Tap-test

- Two identical objects for tapping
- hammer

Audio-test

- None as of now

Track-test

- Tracking system
- Motor/power supply/embedded board for controlling virtual head mount
- Rotatable head apparatus

Separation-test

- Track system for virtual head separation
- System from (3) Track-test

III. Target Audience

The series of sensory replacement experiments will benefit researchers in development robotics.

In our fourth experiment, which evaluates the effects of sensory separation on OBE, future innovations in virtual world implementation can benefit in determining the optimal eye-to-eye spacing. These innovations can range from virtual gaming, virtual conferencing, or virtual socializing. Our work will allow future designers to enrich the consumers' experiences by better understanding how our vision, touch, and audio senses function through induced OBE experiences.

IV. Previous work and research

H. Henrik Ehrsson[1] (2007)

The Experimental Induction of Out-of-Body Experiences [2]

Overview:

This paper describes how an OBE was created using vision and touch (proprioceptive) stimulus.

Process:

The subject was placed on a chair with a HMD connected to two cameras behind them. The subject was tapped on the chest at the same time the 'virtual body was tapped on the chest. This was repeated for two minutes. After that period a hammer was swung at the virtual body, not at the real one. The skin conductance response (SCR) was measured during the test.

Fig. 1. The setup used to induce the out-of-body illusion

Findings:

Researchers found that when the subject had undergone two minutes of chest tapping their SCR for the hammer test was greater than subjects who had not undergone the chest tapping. This implies the mind had begun to believe that it is located where the virtual body is, instead of the real body. A questionnaire was given at the end of the test to measure the strength of the subjects' illusion during the test.

Relevance:

Our second experiment (presented below) addressed the question: If a subject is allowed to move, will the illusion be stronger? This question stemmed from findings from brain plasticity research involving sensory substitution. Studies have found that effective sensory substitution requires the external sensor be under the control of the subject's motor systems (hand, head movement, ect) [2]. In this study, these findings spurred the question of how powerful of an OBE illusion a subject can really have without control of their external sensor. Since sensory substitution can only take place when the subject has control, can an OBE be made stronger if the subject has control of their external sensors as well.

Bigna Lenggenhager [3], Tej Tadi [3], Thomas Metzinger [4][5], Olaf Blanke [3][6] (2007)

Video Ergo Sum: Manipulating Bodily Self-Consciousness [7]

Overview:

This paper explored self-consciousness through a series of experiments.

Process:

Two set of experiments were conducted and both required the healthy participants to wear head-mounted displays (HMD). For the first set of experiments the participants saw their back as it was stroked either synchronously or asynchronously in respect to their virtually seen body for one minute. A set of questions and tasks such as asking the participants to go back to his/her original position as performed after the experiment.

The second set of experiments incorporated virtual fake backs and virtual noncorporeal into the design. The second set of experiments modeled closely as the first set of experiments where the subject was either synchronously or asynchronously stroked in respect to their virtually seen body for one minute.

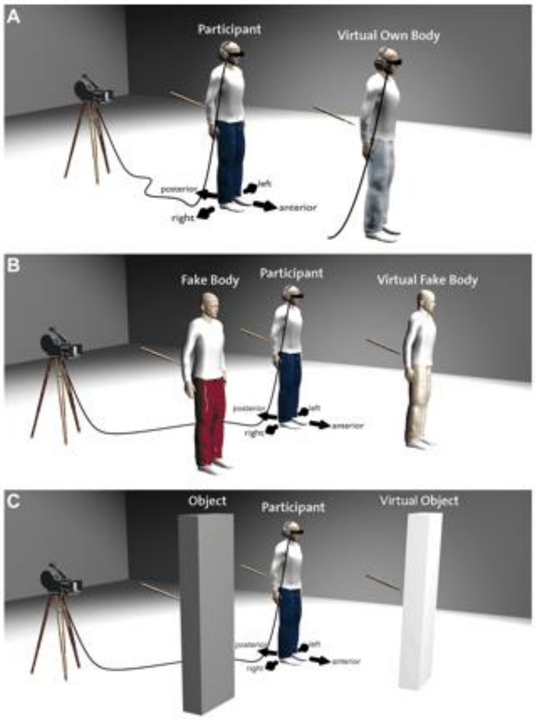

Fig. 2. (**A**) Participant (dark blue trousers) sees through a HMD his own virtual body (light blue trousers) in 3D, standing 2 m in front of him and being stroked synchronously or asynchronously at the participant's back. In other conditions (study II), the participant sees either (**B**) a virtual fake body (light red trousers) or (**C**) a virtual noncorporeal object (light gray) being stroked synchronously or asynchronously at the back. Dark colors indicate the actual location of the physical body or object, whereas light colors represent the virtual body or object seen on the HMD. [7]

Findings:

Researchers found that participants experienced a strong sense of association with the visually presented body to their own. For the first set of experiments the results showed a significant drift towards the virtual body when the subjects were synchronously stroked, whereas there was dramatically less amount of drift towards the virtual body when the subjects were a synchronously stroked. For the second set of experiments the results showed a significant drift towards the virtual body when the subjects were synchronously stroked with respect to the fake and real backs and the drift was almost non-existent in the case of the noncorporeal object. There was no effect in the case of asynchronously stroking with respect to the noncorporeal object.

Relevance:

The *Video Ergo Sum: Manipulating Bodily Self-Consciousness* paper's findings showed that the strongest OBE occurs when the subject's visual and touch senses were synchronously integrated with respect to a virtual body closely related to their own. Those conditions will be used with the proposed experiments and touch senses will be replaced with audio senses.

V. Schedule

The following schedule will be followed to complete the project:

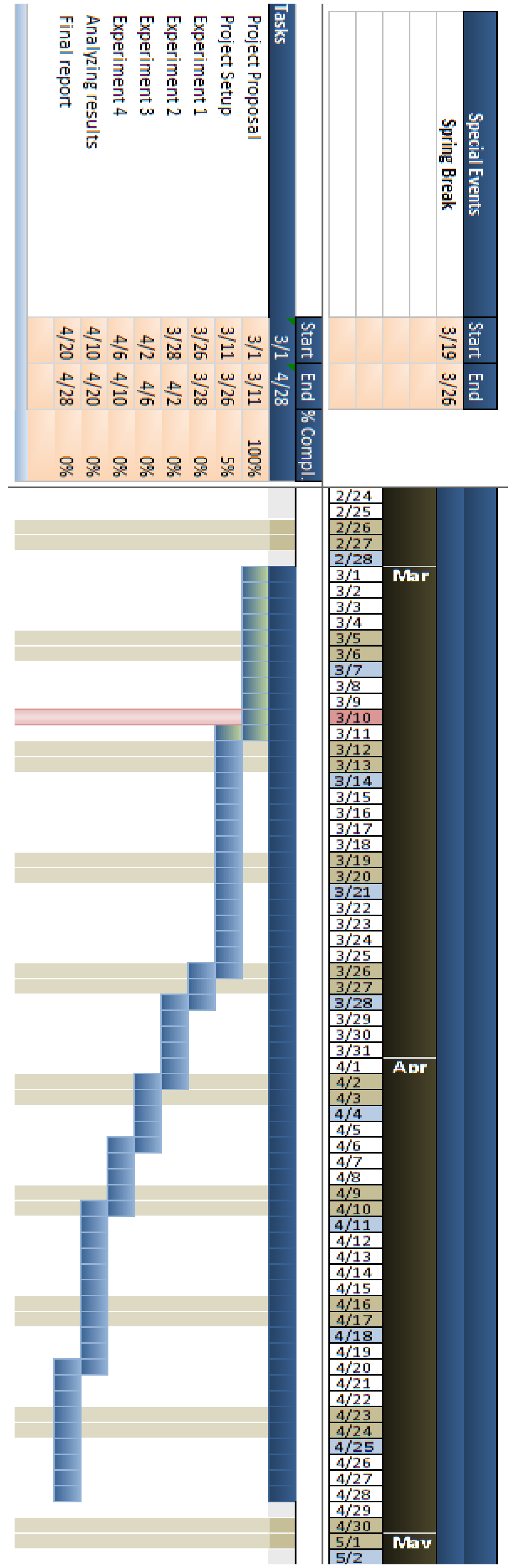

Fig. 3. Tentative schedule to be followed for the project

VI. Proposed Design

Experiment 1

Tap-test : reproduce experiment with visual proprioceptive stimulus

Overview

This experiment is a replication of Henrik Ehrsson's experiment discussed in the Previous Work and Research section. The goal is to reproduce the exact OBE results using vision and touch (proprioceptive) stimulus described in Ehrsson's *The Experimental Induction of Out-of-Body Experiences* [2].

Equipment

- Two webcams
- Two microphones, with artificial ear
- HMD
- Noise cancelling earmuffs to go over headphones
- Stand/mount for virtual head
- Computer with two unused VGAs and VLC media player to run video to HMD
- Two identical objects for tapping
- Hammer

Design

The subject was placed on a chair with a HMD connected to two cameras behind them. The subject was tapped on the chest at the same time the 'virtual body was tapped on the chest. This was repeated for two minutes. After that period a hammer was swung at the virtual body, not at the real one. The skin conductance response (SCR) was measured during the test. A more detailed design process can be found in Ehrsson's *The Experimental Induction of Out-of-Body Experiences* [2].

Setup

The setup is a replication of Ehrsson's *The Experimental Induction of Out-of-Body Experiences* [2].

Hypothesis

The result of this experiment should be identical to Ehrsson's *The Experimental Induction of Out-of-Body Experiences* [2].

Technical Considerations

The technical considerations are identical to Ehrsson's *The Experimental Induction of Out-of-Body Experiences* [2].

Constraints

The constraints are identical to Ehrsson's *The Experimental Induction of Out-of-Body Experiences* [2].

Diagrams

Please refer to figure 1.

Experiment 2

Audio-test : stationary head, walk around virtual head

Overview

This experiment is designed to study the effects of moving a subjects point-of-view for their visual and audio input to a third person perspective. A virtual head is created outside of the body which provides that visual and audio inputs for the subject. Visual and sound cues will be created around the virtual head. The experiment will test to see if an OBE can be created using visual and audio replacement.

Equipment

- Two webcams
- Two microphones, with artificial ear
- HMD
- Noise cancelling earmuffs to go over headphones
- Stand/mount for virtual head
- Computer with two unused VGAs and VLC media player to run video to HMD

Design

A head mounted display (HMD) will be placed on the subjects face so their vision is controlled by the system. The HMD takes as input two VGA cables, on for each eye. The VGA cables will be connected to a computer. The computer will be running VLC media player to display video over the VGA cables. VLC will be displaying the video from two webcams which act as the eyes for the virtual head.

A pair of noise cancelling headphones will also be worn to control their audio inputs. The headphones will be plugged into a computer. The computer will send the headphones the audio from the two microphones on the virtual head. This will allow the microphones on the virtual head to act as the ears for the subject.

Setup

1. Give subject noise cancelling headphones and HMD.
2. Place cameras and microphones corresponding to eyes and ears behind subject.
3. Subject now sees and hears everything as if they were located at the camera, will also see their own body from behind.
4. Stimulate the subject by walking around the camera and creating noises and visual cues (bouncing a ball, clapping hands, snapping fingers, ect)
5. See if a similar out-of-body experience is produced via questionnaire, which will measure subjects' anxiety level from stimulus that effect only the virtual body

Hypothesis

The expected results of the experiment are as follows:

1. The subject will have an OBE.
2. The questionnaire given to the subjects will reflect whether they were in the OBE or control group.

Technical Considerations

The noise cancelling earmuffs to go over headphones needs to be capable of cancelling out all background and foreground sound going into the participant's physical audio input. Also the audio input and the visual input of the virtual system needs to be synchronous with no delays. The microphones need to be semi-directional to replicate the participants physical audio inputs.

Constraints

The test subject is restricted to any movements. The test subject is not allowed to touch any objects in his/her environment.

Diagrams

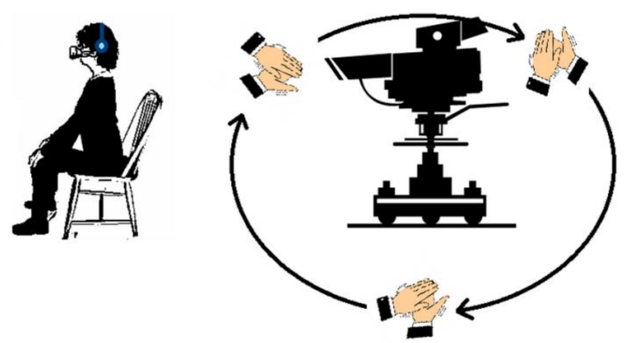

Fig. 4. Experiment 2 Setup. The subject is sitting behind the camera with Noise canceling headsets and HMD in place while virtual visual and audio inputs in respect to the camera are fed into the subject.

Experiment 3

Track-test : use head tracking to allow horizontal (one degree freedom) movement

Overview

Much like Experiment 2, this experiment is designed to study the effects of moving a subjects point-of-view for their visual and audio input to a third person perspective. Unlike the first experiment, however, this one allows the subject some level of control over their virtual head. The virtual head will follow the movement of the subject's real head. Visual and audio experiments similar to the first experiment will be used in an attempt to create an OBE. This experiment aims to compare and contrast the potential OBE from the first and second experiments.

Equipment

- Two webcams
- Two microphones, with artificial ear
- HMD
- Noise cancelling earmuffs to go over headphones
- Stand/mount for virtual head with one degree of freedom
- Head tracking system
- Computer with two unused VGAs and VLC media player to run video to HMD

Design

For this experiment a computer controlled rotatable virtual head will be constructed. The constructed head will be coupled with the subjects head such that a strong correlation exists between their movements. The virtual head will have two cameras and microphones as in the previous experiment. The virtual head will be placed on a rotatable stand and connected to a servo motor. The motor will be able to turn the head 180 degrees left and right. The motion will be limited to left and right turning only. The motor will be controlled by a PWM sent from an Ardrino microprocessor. The microprocessor will receive commands from a desktop computer running software developed for the project. The software will receive data from an already existing head tracking system in Iowa State University's Virtual Reality Application Center (VRAC). The data will include all information necessary to know the head's position. The movement from the previous data point will be calculated and a command will be sent to the microprocessor instructing the motor to turn correspondingly.

The HMD and headphones from Experiment 1 will be used. Please see the corresponding design section for further details.

Setup

1. Sit subject down on chair
2. Place HMD, noise cancelling earmuffs and head tracking attachment on subject
3. Instruct subject on sitting upright and only moving head in one allowable degree of freedom
4. Start recording and logging data
5. Start tracking system
6. Walk around virtual head (camera) and create visual and auditory cues
7. All subject to slowly turn head and watch events in the one allowable degree of freedom
8. Continue experiment for 5-15 minutes
9. Turn off system
10. Give subject questionnaire to measure OBE

Hypothesis

The expected results of the experiment are as follows:

1. The subject will have an OBE.
2. The OBE will be more profound in experiment three than experiment two.

Technical Considerations

Head tracking system is in Iowa State University's Virtual Reality Application Center (VRAC). The tracking system has a camera and head-mounted apparatus which are used to record the coordinate, pitch, roll and yaw of the head. This data is transmitted using Virtual Reality Peripheral Network (VRPN). A client program can be developed in C which reads information from the VRPN.

The latency of the head tracking and virtual head movement system may cause issues. If the virtual head doesn't respond quickly enough with respect to the subject's head then the experiment almost surely will be unsuccessful.

Constraints

Subject may only move head in one degree of freedom, 180 degrees left and right. Subject may not move other parts of body, only head.

Diagrams

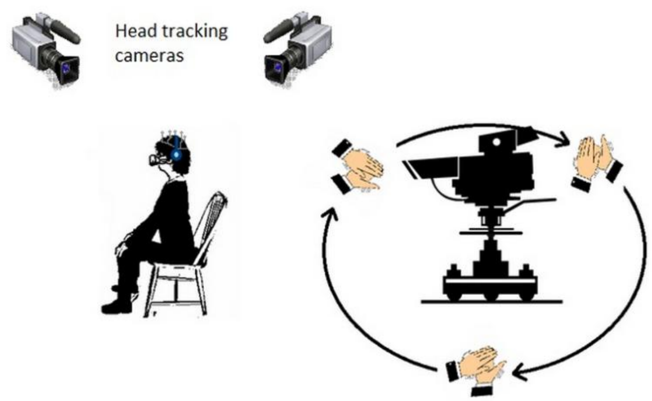

Fig. 5. Experiment 3 setup. The subject is sitting behind the camera with Noise canceling headsets and HMD in place while virtual visual and audio inputs in respect to the camera are fed into the subject. Two head tracking cameras is set in place to accommodate any head movements.

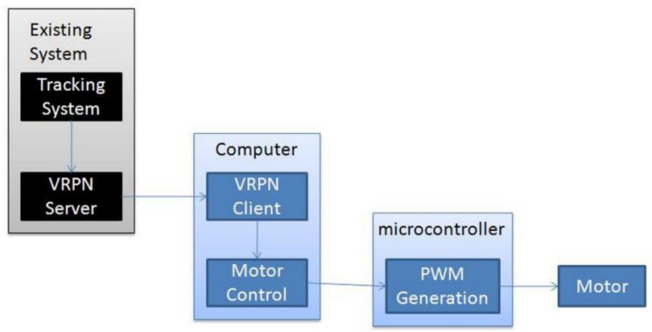

Fig. 6. Experiment 3 - Block diagram

Experiment 4

Separation-test: change eye/ear distance on virtual head and see how sensors are affected

Overview

From our previous experiments, we will determine whether individuals can experience OBE through auditory and visual perception.

Particularly, the separation of the webcams will create conditions of lower side vision field when the webcams are closer together and larger side vision field when the webcams are father apart. A visual diagram is available in Figure 9. Such tests have not been documented in previous research. Since we do not have prior studies to draw upon, we are uncertain how our subject will react to the distortion of increased or decreased vision field.

However, we believe that distorting the amount of side vision will affect the conditions and experience of OBE. We will try to identify commonalities in the responses we receive from the subject and compare the results to Experiment 2. Should there be noticeable differences, we will try to explain them or recommend future work to identify potential causes.

Similar to Experiment 2, we will use the same equipments, setup and questionnaire to judge the subject OBE experience. In addition, we will implement a motor mechanism to control the webcam separation.

Equipment

- Two webcams
- Two microphones, with artificial ear
- HMD
- Noise cancelling earmuffs to go over headphones
- Stand/mount for virtual head
- Computer with two unused VGAs and VLC media player to run video to HMD
- Arduino board
- Gear motor
- Servo-motor

Design

Give subject noise cancelling headphones and HMD. Place cameras and microphones corresponding to eyes and ears behind subject. Subject now sees and hears everything as if they were located at the camera, will also see their own body from behind. Stimulate the subject by walking around the camera and creating noises that also have visual cues (bouncing a ball, clapping hands, snapping fingers, etc.).

See if a similar out-of-body experience is produced via questionnaire. Perform this setup with varying vision gap. This is done by programming the arduino board to control a gear motor that increases or decrease the spacing between the two webcams.

Setup

1. Configure the webcam spacing as specified in Figure 8 for male and female subject
2. Sit subject down on chair
3. Place HMD, noise cancelling earmuffs and head tracking attachment on subject
4. Instruct subject on sitting upright and only moving head in one allowable degree of freedom
5. Start recording and logging data
6. Start tracking system
7. Walk around virtual head (camera) and create visual and auditory cues
8. All subject to slowly turn head and watch events in the one allowable degree of freedom
9. Continue experiment for 5-15 minutes
10. Turn off system
11. Give subject questionnaire to measure OBE

Hypothesis

The expected results of the experiment are as follows:

1. The subject will have an OBE.
2. The subject will not notice the separation of the virtual head up to a threshold.

3. There will be a threshold distance at which the subject will no longer be able to see or will notice the separation of the virtual head.

Technical Considerations

The accuracy of the gear motor in setting the spacing between the two webcams will be limited due to no feedback information from the gear motor. We will program the Arduino to have a standard interval of spacing and control that spacing by push buttons. This will remove the need for a shaft encoder to provide feedback information on the position of the gear motor.

For the servo-motor, it will be limited in its turning degree. The servo-motor will be capable of turning180 degrees. This will mirror the turning limitation of humans.

A local power supply with higher current might be needed to power the gear motor and the servo-motor. Due to the power limitation of the Arduino, the additional power supply will also require a motor driver circuit in order for the Arduino to control the motors. Should that be the case, the L298N driver IC will be use to resolve the power constraint.

Constraints

The subject will be limited in turning 180 degrees in the frontal position.

From [8], we identify work from Evereklioglu et at. to have the most comprehensive statistical results. We will limit the vision spacing for male and female according to the min and max spacing found in Evereklioglue's work [9], shown in Diagram A. We will use the average vision spacing as the controlled configuration. We will then vary the vision spacing by 5mm interval and observe any changes in the OBE from the questionnaire. Our final configuration for the spacing can be viewed in Figure 8. The spacing is within the results from [9] and uses the extremes to test for effect.

Due to the large variation in the vision spacing in both male and female, there will possible situation where the subject will feel discomfort from the shift in their normal stereoscopic vision. We will monitor the behavior of the subject and maintain their health as our main priority.

Diagrams

52	62.6	75	Male, age 15–25, combining all D results in Table 6
43	60.8	74	Female, age 15–40, combining all D results in Table 6

Figure 7: Source Evereklioglu[2], Measurements in mm

Webcam Spacing (mm)	
Male	*Female*
55	45
60	60
75	70

Figure 8: Specified spacing within the results from Figure 7

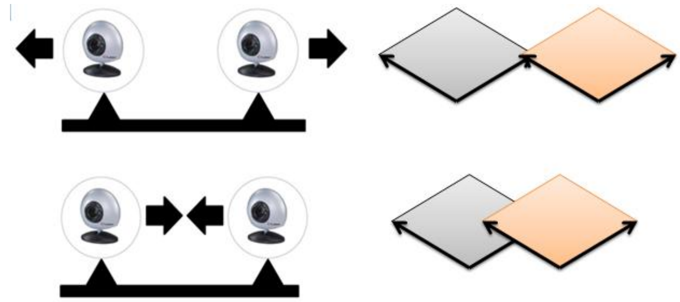

Figure 9: Eye to eye spacing influencing field of vision

VII. Evaluation

Iowa State psychology Professors Carpenter, Shana K., Chan, Jason C.K., or Cooper, Eric E will help to provide questioners about:

- The level of intensity of the OBE felt by the subjects
- Duration of subjects' OBE
- Time required for subject's to feel OBE
- Sensations felt by the subjects during OBE

References

[1] Department of Neuroscience, Karolinska Instituet, Stockhom, Sweden

[2] Ehrsson, Henrik H. "The Experimental Induction of Out-of-Body Experiences." *SCIENCE* 317 (2007). Print.

[3] Laboratory of Cognitive Neuroscience, Ecole Polytechnique Fédérale de Lausanne, Station 15, 1015 Lausanne, Switzerland.

[4] Philosophical Seminar, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany.

[5] Frankfurt Institute for Advanced Studies, Johann Wolfgang Goethe-Universität, 60438 Frankfurt am Main, Germany.

[6] Department of Neurology, University Hospital, 1214 Geneva, Switzerland.

[7] Lenggenhager, Bigna, Tej Tadi, Thomas Metzinger, and Olaf Blanke. "Video Ergo Sum: Manipulating Bodily Self-Consciousness." *Science* 317.24 (2007): 1096-099. Print.

[8] Dodgson, Neil. "Variation and extrema of human interpupillary distance", Proc. SPIE Vol 5291 (2004). http://www.cl.cam.ac.uk/~nad10/pubs/EI5291A-05.pdf

[9] C. Evereklioğlu, S. Doğanay, H. Er, and A. Gündüz, "Distant and near interpupillary distance in 3448 male and female subjects: final results", Turgut Özal Tıp Merkezi Dergisi 6(2):84–91, 1999

Ben Cao (Senior in Computer Engineering) he is interested in the field of developmental robotics and enjoys tackling today's challenges through technology. He enjoyed Alex's HCI 575 course: Computational Perception.

Joshua Clausman (Senior in Computer Engineering) he is enjoys socializing with people and has taken some graduate level courses related to developmental robotics.

Thinh Luong (Senior in Electrical Engineering) he is proficient in embedded systems implementation and has previous experience with arduino programming.