MEETING MYSELF FROM ANOTHER PERSON'S PERSPECTIVE

SWAPPING VISUAL AND AUDITORY PERCEPTION

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ABSTRACT

In this report a state of the art of rubber hand and full body illusions have been reviewed, a prototype created to conduct an experiment in which two persons simultaneously swap their visual and auditory perception. The results describe sensations aroused from this experiment and changes in perceived ownership of the foreign hand and body. Furthermore a method to swap auditory perception of two people has been described, and improvements and uses of body ownership research have being discussed.

1. INTRODUCTION

The sensation of owning a body is a constant percept that is related to every moment in our life, but still we can live without stopping to think about it, even though rare conditions, such as phantom pain or out of body experiences, can force people to pay attention on the percept. Gallagher describes body ownership a "special perceptual status of one's own body, which makes bodily sensations seem unique to oneself, that is, the feeling that 'my body' belongs to me, and is ever present in my mental life." [1] Another commonly used term of the sensation is "embodiment". [2] Without understanding the bodily constrains of ourselves we would have difficulties to coordinate ourselves, and to understand some basic concepts, such as to determine whether the cup I am holding in my hand is part of my body, or whether it is an independent object. Nevertheless, with a simple method in few seconds we can create sensation of a rubber hand belonging more to our body than the hand that has been part of our body since birth. Furthermore, we can create a sensation of owning a different body, that can be of a different gender or have a different skin color. [3, 4, 5]

The body that we own has an affect on how we perceive ourselves, and on how other people perceive us; the type of a body affects how we see the world and interact with it. As Merley-Ponty put it: "Insofar as I have hands, feet; a body, I sustain around me intentions which are not dependent on my decisions and which affect my surroundings in a way that I do not choose" [6]. Modern philosophers tend to explain with monistic theories, that the mind and body are connected, that is a contrast from traditional theories before Aristoteles and cartesian dualism where they are understood separated. [6, 7, 8]

In this report an experiment is presented in which two participants change their auditory and visual perception, and meet themselves from each others perspective. The experiment which is split in three conditions, challenges the user's automatic mechanisms of body ownership and self recognition - should the participant feel being inside the other participant's body watching himself? The most prominent theories explaining construction of sensation of body ownership and the state of the art experiments in the field are reviewed.

Body ownership and mind and body problem have persisted in our minds, but researching the field has been difficult until the recent technological innovations have made it possible to start exploring the field with scientific methods. A perfect test condition would be to test a person with a body against a person who does not have a body, but as this condition remains as a subjective thought play, most of the conditions are based on rubber hand illusion to explore the body malleability and to experiments using technologies such as head mounted displays, which enable to change visual perception from first person's point of view, creating a sensation of being present somewhere else. This knowledge can be applied in different disciplines. Learning to manipulate the sensation of body ownership serves in new areas in telepresence, telerobotics, in virtual reality, applications in medical field such as conducting surgeries with help of robotics and augmented reality in which the precision and accuracy of these simulations can be greatly enhanced. [9] Perhaps in the future it is not necessary to send people to Mars if we can create as immersive sensation by telepresence of actually being there. Moreover, the methods can be applied in social psychology, and to treat people with distorted self perception.

This report consists a state of the art review of rubber hand and full body illusions and presents the most prominent theories explaining the underlying mechanisms of the sensation. Furthermore presenting a prototype, which final version is used in an experiment for 20 volunteers who swap their visual and auditory perception.

2. RUBBER HAND ILLUSION

Botvinick and Cohen presented rubber hand illusion on 1998, which can be conceived as a landmark in body ownership research. In their experiment the subject has both of her hands on a table, but her left hand is hidden from their vision with a screen. On the right side of the screen a rubber hand is placed to a similar position as the user's hidden hand. The subject is informed to look at the rubber hand while the experimenter begins to stimulate both the rubber hand and the hidden left hand synchronously with a small paint brush. [See Figure 1] After ten minutes the subjects were asked to rate in a questionnaire on their feelings of the experience and if there was ownership aroused to the rubber hand. [3]

The experiment revealed that the participants felt the touch of the brush stroke in the location where the rubber hand was placed but also perceived the rubber hand being a part of their body. The questionnaire consisted nine statements and space for an open-ended description of the experience. Three statements: "It seemed as if I were feeling the touch of the paintbrush in the location where I saw the rubber hand touched", "It seemed as though the touch I felt was caused by the paintbrush touching the rubber hand" and "I felt as if the rubber hand were my hand", were agreed strongly in the answers. [3] Follow up research often refers to this questionnaire and uses it as a base for their questionnaires.

Figure 1. Rubber hand illusion

In the experiment's control condition, the haptic stimuli was given in asynchrony and resulted to evoke the illusion average only on 7% of the participants, versus 42% of the participants in synchrony condition. In the second part of the experiment, the subjects were exposed to the stimuli for a prolonged period up to 30 minutes whereafter they were asked to point the location of their left hand with their right hand finger, eyes closed. This resulted as a perceived mislocation of the left hand; the more time haptic stimuli was given, the closer to the rubber hand the participant thought her left hand was located. In the control condition, the displacement was significantly smaller. [3] In subsequent research the illusion is induced with much shorter period of haptic stimuli, as it has been described 9.7 seconds being sufficient. [10]

2.1 Charasteristics

Longo et al. conducted a research on 2008 in order to understand the characteristics of the illusion by using a 27-item questionnaire. After inducing the illusion by similar terms than Botvinick and Cohen, the 130 test participants were asked to rate on Likert-scale their agreement or disagreement on questions such as "it seemed like I was looking directly at my own hand, rather than at a rubber hand", and "it seemed like the rubber hand was part of my body". After principal component analysis of the data, the experience could be divided in five main components: (1) embodiment of the rubber hand, (2) loss of own hand, (3) movement, (4) affect, (5) deafference. The first component is related to feelings in which the participant feels to have control of the hand, to feel it belonging to himself and that it has characteristics of the real hand. The second component, loss of own hand, contains feelings how the participant feels that he loses the control of his hand, and that it is disappearing, where as the third component, movement, consisted feelings such that the participants real hand was moving towards the rubber hand. The component 'affect', describes the event being pleasant, interesting or enjoyable. Deafference occurred only in asynchronic conditions, and contained feelings such as the participant's hand being numb and a sensation of pins and needles in his hands. [11]

The data from embodiment of the rubber hand varied greatly, hence an additional principal component analysis was conducted for this component, revealing three subcomponents: ownership, location and agency. Ownership consisted feelings in which the rubber hand was felt being part of the participants body and how it started to resemble the participants hand, in the location component was categorized the felt displacement of the hand towards the rubber hand, where as agency described feelings of having control of the rubber hand. [11] Longo et al. used the same data set in their follow up study where in was concluded that the similarity of the rubber hand is enhanced once the ownership has been adopted; thus, the similarity of the rubber hand does not lead towards ownership, but ownership creates sensation of the rubber hand's similarity. [12]

Moguillansky et. al explored the induction of the rubber hand in fine detail, as step by step. They divided the experience to different phases; such as in synchronous visuo-tactile stimuli the experience begins as a perception of the tactile stimulation, follows matching the stimulation with visual stimulation, the third phase being incorporating the rubber hand and final phase the illusion to occur. In their report it is described in detail how the illusion proceeds, as an example a quote from the phase three, during the stimuli, before the illusion has occurred: "Actually the longer it lasts the more I have exactly this impression, that it [the illusion] is starting, well the fake hand, I have the impression that it's mine." Around the same phase the ownership to the real hand started to diminish. Their results show the affect of the illusion as the test participants are surprised of its vividity. [13]

2.2 Measuring the illusion

Both psychological and physiological methods have being used to measure the illusion. Tsakiris et al. designed a method to measure 'proprioceptive drift', that is the quantity of the change in the perceived position of the participant's hand between the start and the end of the experiment. In their experiment, the participant was looking at the rubber hand through a double sided mirror, providing a possibility to make the rubber hand disappear after the illusion was induced. A ruler was projected on the mirror and the test participant was asked verbally where in the ruler scale the participant felt his hand was located. The amount of mislocalizing the hand position towards the rubber hand resulted as the amount of proprioceptive drift. [Figure 2] [14]

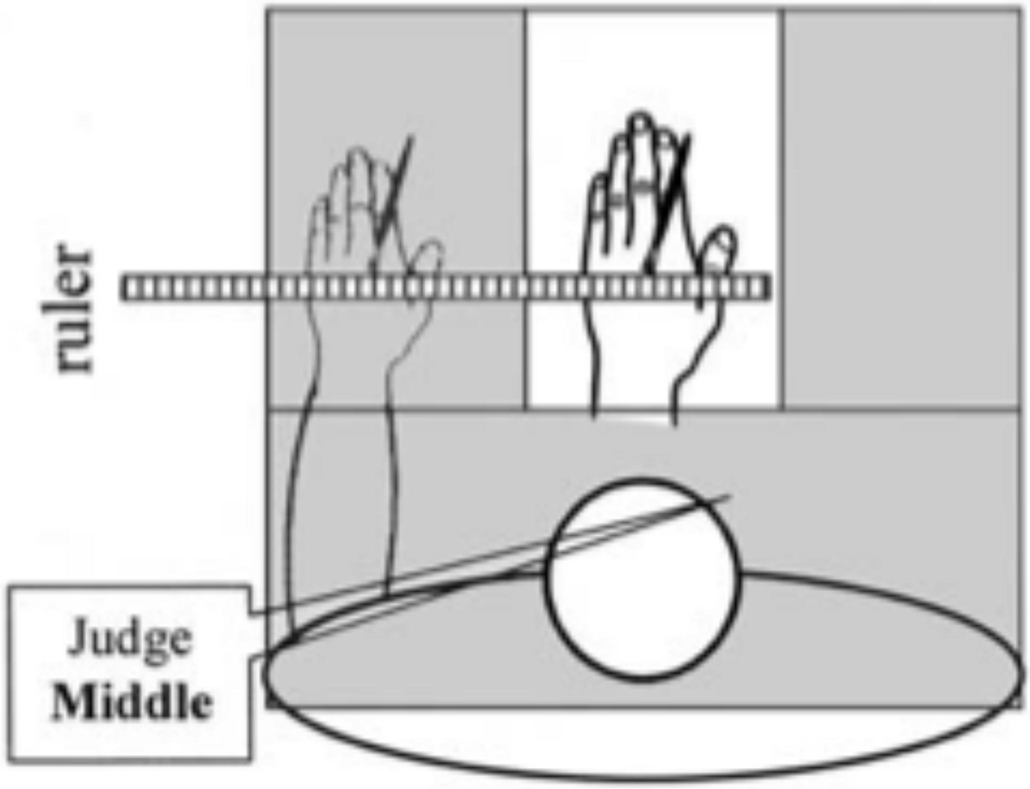

Figure 2. Measuring proprioceptive drift. Figure from [14]

Galvanic skin response can be used to measure the emotional changes of the participant during the illusion. As an example, a radical changes in the measurements are expected when threat is evoked to the rubber hand, such as stabbing a needle or a knife into the hand, since the participant's sympathetic nervous system elicits sweat when threat occurs, indicating that the rubber hand is perceived as part of the body. [15, 4] Also skin temperature has been used as a measurement, as Mosley presents that the participant's hand gets 0.11-0.27 Celsius degrees lower after an ownership has been established to the substitute hand. [16].

Slater presented a technique to measure the level of ownership by measuring the breaks of the illusion, since either the participant is in 'illusion state' or in 'no illusion state'. The participant reports every time a change in his state is happening, whether the embodiment has been established or it has been lost. Lesser amount of changes indicate a stronger illusion. [17] The strength of the illusion correlates also in cerebellar and premotor activity, hence fMRI could be used objectively to measure the illusion, but in many cases it would be hindering test conditions. [18]

2.3 Limitations, constrains, theories

Tsakiris and Haggard confirmed that the illusion did not occur if the rubber hand was in incongruent position to the participant's hidden hand. In their experiment the rubber hand was set horizontally on the table while their hidden hand was postured vertically. The potential affection of visual variables was minimized, as both the hand of the participant and the rubber hand were wearing white gloves. Also Lloyd measured constrains positioning the rubber hand and found that the illusion was most vivid while the rubber hand and the participants own hand were closer to each other, 17.5 cm apart. The distance between the fake and real hand was measured to be up to 30cm, but in longer distances there was a decrease on the perceived ownership. [14, 19]

Besides the postural incongruency other constrains were described: (1) the rubber hand and the participant's hand identity must be congruent, i.e. left rubber hand cannot be used if the the participant's right hand is being stimulated, and (2) the object must resemble their own, real hand. They describe using a wooden stick instead of a rubber hand, evoked no ownership. [14]

This finding challenged Armel's and Ramachandran's straight forward bottom up -theory as the explanation of the cause of ownership. They suggested the illusion being purely result of a bottom-up mechanism and based on Bayesian model averaging, disregarding all cognitive processes inducing an ownership; visuo-tactile correlation being sufficient. [20,21]. Using this model is approved that brain could group basically any objects belonging to the body, if correlated temporal stimuli between sensory modalities is being provided. Galvanic skin response was used to solidify the results of the experiment, in which the rubber hand was threatened after ownership had been induced stimulating simultaneously the participants real hand. Secondly, they experimented threatening the table the participant's hand was on. The results indicated changes in galvanic skin response also while the table was threatened. Later, Takiris and Haggaard experimented by using a wooden branch instead of a rubber hand and found out that no ownership was manifested, in contrary while using the same protocol to a rubber hand. Hence, they proved that the origin of the emotional response of threat to the table in Armel's and Ramachandran's test must have had different origin than perceived ownership to the table, and that the ownership cannot be entirely a bottom up process. [14, 21] In addition, neurological studies have found that the self-attribution of a limb is created in frontal and parietal association cortices by researching people with damage in this brain region and their potentiality to fail to recognize their own body part, even though they would be still able to perceive somatic stimuli, thus supporting the view that the illusion cannot be entirely a bottom up process. [22] The rubber hand illusion does not occur for everybody. Lloyd presents that the illusion can be established for approximately 80% of the test participants. In his test the 21% did not perceive ownership, while in Ehrsson's experiment from 2005 the percentage was around 22%. Ehrsson later summarizes the illusion to occur average 70% of the participants. [19, 23, 24]

2.4 Mechanisms inducing ownership

The underlying mechanisms inducing an ownership are not completely understood. The original hypothesis from Botvinick and Cohen suggested the illusion resulting from three way interaction between visual, haptic and proprioceptive senses. [3] The participant's visual percept of the rubber hand being touched while his real hand is simultaneously stimulated binds a coherent event and results to a mislocation as the decision on made over proprioception on the behalf of visual perception.

Ehrsson supports their hypothesis and monitored brain activity with an fMRI scanner during a variation of the original rubber hand illusion on 2005 in which the experiment was conducted without visual sense, as a somatic rubber hand illusion. In the experiment the participants were blindfolded, having their hands on a table, a rubber hand between them. The experimenter grabbed the participants left index finger and touched the rubber hand in synchrony with touching the participants right hand. (See Figure 3)

Figure 3. Somatic rubber hand illusion. Figure from [23]

Questionnaire results indicate strong statements from the participants believing them touching their own hand instead of the rubber hand. His findings included that while the ownership occurs, the neuronal activity in intraparietal cortices, ventral permotor cortices and the cerebellum and other areas is increased as the visual, proprioceptive and tactile percepts integrate. Ehrsson suggested that increased activity in these regions reflects to the neural processing of multisensory signals.[23, 24]

Petkova et al. conducted a similar somatic rubber hand experiment using blind participants, finding out that the the ownership was not experienced. The reason for the rejection was not completely understood, but it was suggested that blind individuals cannot be as elastic in their body presentation than sighted individuals, due to their reduced multisensory experience in their childhood. [25] It is not understood how then blind people form their body ownership, which seems to be more firm and steady. Perhaps their bodies could be more sensitive adopting a foreign limb as an example with aural and haptic stimuli, as their perception is the surroundings is based on different cues than to a strong dominance of the visual sense on sighted people.

2.5 Proprioceptive rubber finger illusion

Another variation of the rubber hand illusion, shows ownership to a rubber finger - 'a finger grasp illusion', that has been presented to evoke only from proprioceptive cues. In a recent experiment conducted by Heroux et al., first the participants' haptic sense was temporally numbed by blocking all the input from skin and joint receptors from right index finger, left index- and thumb finger by blocking the nerves with lignocaine, leaving the muscle spindle afferents as the solitary receptors contributing the illusion. Subsequently, the participants were sat front of a table, placing their hands into a box, where into they could not see; thus, visual and haptic senses being obstructed, leaving only the sense of proprioception left.

The box had two levels, in which to the lower the participant placed his right hand's index finger into a holder for the finger. Left hand was placed on the first level, in which the participants were holding a rubber finger with their thumb and index finger which horizontal movements were controlled with a joint by the movements of the right index finger. Each time when the participant moved his right index finger, the rubber finger moved in the grip of his left hand, captured not by the skin receptors, but proprioception. [26] (See Figure 4)

The experiment was tested against a control condition of asynchronous movement, in which the feedback to the rubber finger occurred different time than the movement of the right finger, and also against a group without the digital nerve block, to verify that only motor movements would have an affect to the conclusion (i.e. numbing haptic sense was working).

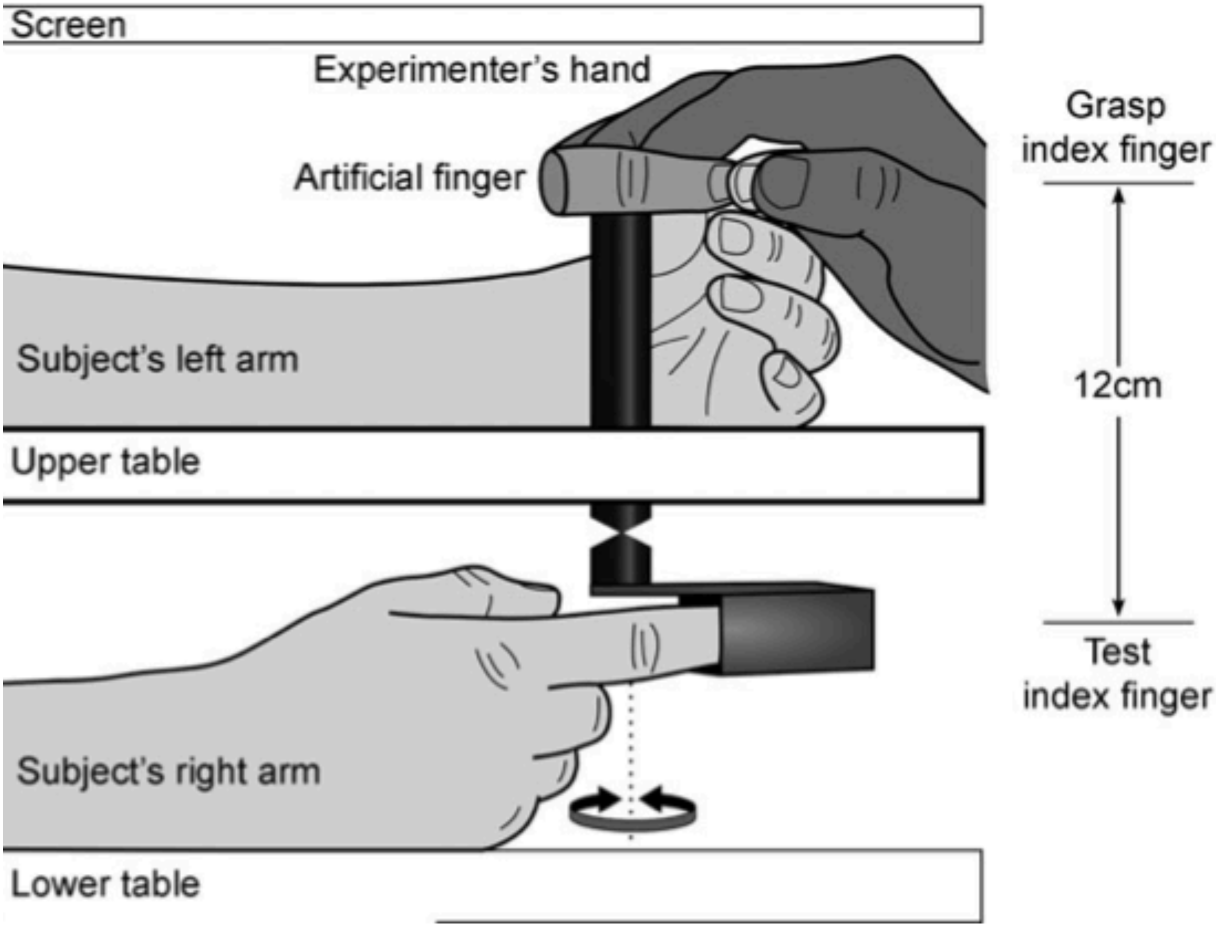

Figure 4. Finger grasp illusion. Figure from [26]

After the experiment, the participants were asked to rate in seven-point Likert scale if they feel they were holding their right index finger with their left hand. The results indicated that just holding the artificial finger without movement did not create the illusion itself neither did asynchronous movement, in contrary to the synchronic movement where ownership was noticed. Heroux et al. suggest that the ownership might be created because of the consistency of the incoming repetitive stimuli. Each time a certain muscle action is made, the feedback is the same: the artificial finger becomes a real one as the actions correlate with each others and the brain concludes it to be the most likely scenario. Hence, the prediction creates the illusion of ownership together with the repetitive stimuli. [26]

2.6 Comparing modalities

Kalckert and Ehrsson in their recent study compared the strength of the rubber hand illusion either it being self-induced or induced by an experimenter. In their experiment, the participant's hand was located in a box, that was connected with a stick to a rubber hand's index finger which was on the sight of the participant on top of the box. Every time the user would raise his index finger the rubber index finger would imitate the movement. (See Figure 5) [27]

Figure 5. Actively triggering rubber hand illusion. Figure from [27[

The participants learned the causality, that is the movement of the substitute hand originating from their initiative and engaged quickly the wooden hand belonging to themselves, similarly as if the wooden hand and their own hand was stimulated by the experimenter. The experiment consisted three conditions: the classic rubber hand illusion, the self-induced illusion and thirdly, an experiment that used the same setup from the self-induced illusion, but the experimenter was moving the participant's finger instead of active movements by the participant himself. The experiment was measured subjectively by using a questionnaire that split the asked question to the themes of ownership and agency and objectively by measuring proprioceptive drift. The results indicated equal strong level of ownership whether the illusion was triggered by the experimenter or the participant herself. [27]

Even though it could be assumed that the sensation of ownership to be stronger the more modalities are engaged, the results indicated that by triggering the illusion by using different modalities can create the same results, here in all three conditions as the measured ownership was not higher in one condition than in another. The traditional rubber hand illusion elicits from tactile and visual information, but in the presented condition in which the participant activates the rubber hand himself the illusion elicits among visual perception from skin receptors, muscle spindles, joint receptors and cognitive commands with the predictions of the action. [27, 28, 29]

2.7 Summary

The most accepted theories of the mechanisms of creating an illusion of owning a superficial limb point to the direction of multisensory interaction, that is not entirely a bottom up process. It has been proven that ownership cannot be created to every element with synchronous multimodal stimuli, due to the evidence that the desired element must be corporeal, and its postural form has to be aligned. These constrains present cognitive processes, even though there is a degree of plasticity in the adaption process, such as the color of the skin does not have to match - the more important factor being the temporal and spatial range of the illusion. The relationship between neuronal mechanisms and cognitive processes is problematic to present and to define, but the evidence shows that they interact. [5, 24, 27, 30]

No specific modalities are responsible establishing the illusion, since different modalities can create equal strong sensation of an ownership. [10,27] Also, imagined stimuli or a prediction of a stimuli can be bind together with a real stimuli. It has been presented that a single coherent percept can be partly prediction and partly visual stimuli. The test participants have reported to feel the haptic stimuli while the brush stroke is still approaching the rubber hand. [26, 31, 32] More research need to be done to understand the relationships between modalities and multisensory predictions. As a new field of research still the very fundamentalistic bases can be challenged as an example Ferri et al. in their research from 2013 claiming body ownership being completely a top down process. [31]

The rubber hand illusion occurs generally around 70-80% of the test participants. [19, 24] The reason for this immunity is not understood, and overall research on individual factors contributing to ownership needs to be further researched. Ehrsson suspects that individuals with higher understanding of their bodily functions and who are trained to be aware of their proprioception such as athletes, could be immune or have reduced sensitivity adapting the illusion. [24] This is supported by evidence from research conducted using individuals with eating disorders and other interoceptive individuals. [33, 34] Perhaps also blind people have naturally more interoceptive abilities making them immune to bodily plasticity among their reduced multisensory binding. As the individual differences are not understood, researching the people who are not able to create the ownership can help to understand the origins of the illusion.

In the conducted researching the rubber hand illusion the test designs have slightly varied from each other as an example in terms of the appearance of the rubber hand, in the stimuli duration, or in the applied force of the stimuli. On the other hand there are subjective variability, as different physical condition and bodily awareness are a factors on the level of inducing an ownership. Some research has used only one measure, as an example solely a questionnaire or proprioceptive drift. These factors cause the results vary from each others in some degree of freedom making their comparison challenging.

3. BODY OWNERSHIP

As we can induce an ownership to a rubber hand, research has shown that similar ownership can be induced to a whole foreign body. Conducted experiments range from measuring ownership from mannequins to virtual avatars. The research field is blooming due to the new technological innovations in virtual reality that have made possible to create virtual surroundings easily. Many of the experiments are using head mounted displays, which due to increased computational power and better graphics and resolution enable real-feeling experiences from first person's perspective. [4, 35]

Ehrsson demonstrated on 2007 an illusion of being outside of oneself's own body. In the experiment the participant was sitting on a chair and wearing a head mounted display which received a stream from two CCTV cameras; the left camera to the left eye and the right camera to right eye. The cameras are placed two meters behind the participants facing the participant's back. The experiment resembled rubber hand illusion by triggering the illusion with simultaneous haptic and visual stimuli, as the experimenter is touching the participants chest with a stick and doing similar movement front of the camera as like touching 'an imaginary chest'. The test participant sees a stick coming closer to a location where his chest is from first person's perspective and simultaneously sees his own back. Measured both with synchronous and asynchronous stimuli, the results indicated a feeling of being outside of own body and looking at their own back. [35] (See figure 6)

Figure 6. Experiment to induce an out of body experience. Figure from[35]

The installation causes a sensation of being present somewhere else, suggested (1) due to the correlated haptic and visual stimuli, and (2) due to the fact that visual perception is substituted to the stream from a head mounted display. The first person's perspective has an essential role in the illusion. We have learned to gather the visual information from a fixed point of our eyes, hence we can rely to our memory and past percepts while gathering new sensory data. When the brain does not constantly have to suspect and to monitor the visual information source to be in a different place, our accuracy is better and spatial awareness faster and makes it easier localizing and identifying ourselves in an environment - this is also probably why in evolution we have developed the sense of body ownership. Due to the strong role of the visual sense when forming a single coherent percept, bottom up percepts can in some level override top down processes when determining our presence. [4, 36, 37]

There are various descriptions of presence, but the term can be understood as a subjective sensation of 'being there', where as 'there' is not necessary connected to oneself's physical location. Similarly, telepresence can be described as 'being somewhere but not physically going there'. [38, 39] The experienced presence can be influenced as an example with auditory or visual stimuli. The easier it is to alter the presence the more immersive the developed system is. The level of the immersion can be categorized to non-immersive, semi-immersive and fully immersive systems. Watching a film from a computer is usually non-immersive system, even though one can feel disappearing to the movie world. Semi-immersive systems are often large projection screens and fully immersive systems head mounted displays, which block the surrounding visual sensory information substituting it with artificially created content. [40]

3.1 First person's perspective versus third person's perspective

Petkova and Ehrsson explored further the importance of the first person's perspective as a part of their experiment of owning a mannequin body. In the experiment, two CCTV cameras were placed on a head of a mannequin pointing to its torso, which supplied a stream to a head mounted display of the test participant. Whereafter, the mannequin's and participant's torsos are subjected to synchronous visual and haptic stimuli. In a control condition the stimuli was asynchronous. The mannequin was also threatened with a knife. During the test the participants' galvanic skin response was measured, and after the test they were asked to answer a questionnaire. The results indicated that 17 participants out of 20 felt the mannequin body as their own when the visuo-haptic stimuli was synchronized in contrary to an asynchronic condition where in only 7 participants out of 20 experienced the illusion. The same test was conducted but by setting the CCTV cameras to film the mannequin's torso from 3rd person's perspective. As a result, the first person's perspective condition results were significantly higher rated in the questionnaire and measured in the galvanic skin response. Similar conclusions can be withdrawn from Lenggenhager et. al experiment where the users were observing a mannequin from third person's perspective. [41, 42]

Ehrsson suggests that the multimodal tactile, visual and proprioceptive information are linked to egocentric perspective hence the same information will not cause the same effect from third person's perspective [4] As an example, when we recognize ourselves in a mirror, or in a photo i.e. from a third person's perspective; we still don't feel that we actually would be in the mirror. In an experiment, a participant was sitting in a chair her own face presented in a screen. Brush strokes were applied to both of the representation and the participant herself while the image started to change its characteristics, ultimately not resembling the original picture in the end. Participants could recognize the presented face as theirs, even though it did not resemble them anymore.This sensation is significantly weaker or not comparable to the sensation of body ownership and referred as self recognition. Similar adopting of the presented face does not occur most likely since the presentation is on third person's perspective. The strength of the first person's perspective prevents us to have a strong sensation of ownership. [41, 43]]

3.2 Plasticity of our bodies

It was further explored that non-corporeal objects, such as chairs, tables or boxes do not trigger the illusion; the substitute body must resemble a body, but in flexible terms. [4] As an example, a barbie doll is sufficient enough to resemble a body. Van der Hoort et al. conducted experiments using the same paradigm but instead of the camera to be pointed onto a chest of a mannequin, visual perception was substituted for different size of legs, the smallest being a barbie doll legs and the largest giant legs reaching 400 cm. The participants were laying on a bed and saw the given artificial legs while synchronous haptic stimuli was given. The results indicated that it is possible to feel ownership of these limbs which proportions radically differ from the one the participant is used to. Also, it was confirmed that the gender of the substitute body is not important, as also presented in the Ehrsson's earlier experiments. [4, 44]

Several experiments have been conducted to further understand the plasticity of body ownership, many of them using computer generated images instead of stream from cameras. Slater et al. created an illusion in which the participant is using a head mounted display and immersed into a virtual environment. The participant's avatar is a little girl, sitting on a chair in a room where on the right side the participant can see herself in a mirror. The experiment continues when a woman enters the room and pats the girls shoulder for seven minutes and eventually slaps the the girl to her face. The participants were tested in different conditions: (1) the simulation was seen from first or third person's perspective, (2) the avatar's movements were synchronous or asynchronous related to the subjects movements, and (3) the shoulder patting was either synchronous or asynchronous.

Their results indicate that the first person's perspective is the main trigger the illusion of body ownership, the movement did not have a particular effect, and that the haptic stimuli had some effect. [45]

Kilteni et al. presented an extended arm illusion, in which virtual avatar's right arm grows three times the length of a normal arm. No external haptic stimuli was given in the experiment, but their virtual body with its long hand responded to their movements naturally, thus this active participation can be understood as self-triggered stimuli. The experiment summarizes that the participants felt the long arm as their own. [46] Similarly, Normand et. al explored that the size of the substitute body's belly can be extensively larger, still the participant adopting the body. [47] The colour of the substitute body's skin does not have an effect either, as Peck et al. describe in their experiment in which light skinned participant's were given a black person's avatar. [5]

Kokkinara and Slater experimented on the visuo-motor synchrony. They created a virtual body for the participant which legs he could move, by moving his own legs which movements were tracked. In addition to measure the illusion with a traditional questionnaire, the participants were asked to verbally inform the experimenter every time there was change in the state of the ownership; whether it was that the person established an ownership to the virtual limb or lost the ownership. The lesser amount of changes was informed, the more constant the illusion was. This new approach introduced a method to research which factors are supporting the illusion and which are decreasing it. Their results indicated that in synchronic condition the virtual leg was perceived as one's own. If the leg did not follow the movements of the participants, the illusion broke. [17]

Petkova and Ehrsson placed the CCTV cameras on head of the experimenter, causing the participant using a head mounted display to see from the experimenter's point of view.
The experimenter and the participant hold their hands as if they would be shaking them, and were instructed to look at them, and to squeeze hands in a random rhythm. In addition to a questionnaire, the experiment was evaluated by measuring skin conductance response while the experimenter's hand was threatened with a knife. The self-inducted visuo-haptic stimuli and seeing the experimenter's hand for first perspective, caused the participants to report as they would be shaking their own hand using the experimenter's hand, and feeling the experimenter's hand more threatened than their own. [4] (See Figure 7)

Figure 7. Participant shaking his own hand with the experimenter's hand. Figure from [4]

Similar constrains and characteristics occur to the full body ownership illusion than to the induction of ownership in rubber hand illusion. However, the illusions supplement each others, but are not comparable on one to one. Illusion of owning a foreign body is established by using far more sensory data, hence more complex mechanisms are most likely involved than in the classic rubber hand illusion. Even thought the underlying processes remain uncertain, both of the illusions are seemingly easy to trigger. As like in rubber hand illusion, the participant's own limb or a body does not have to resemble her own body, since ownership can be felt to a child's body or to a different skin colored avatar's body, but - the prerequisity is that must resemble a body - to be corporeal.

4. VIRTUAL REALITY SETUPS

As reported before, we are used to gather the visual information from a fixed point of our eyes, and altering this very fundamentalistic property can alone cause a strong sensation of altered presence. The congruent movements with our avatar in a virtual world induce the illusion in general similarly as actively triggering the rubber hand illusion by the foreign hand's index finger moving in synchrony with our own index finger's movements. [27]. This induced agency fits well with virtual reality control device Razer Hydra, that allows the individual to see and control his hands in virtual world. The device provides more natural controls to the virtual world but also helps to induct the ownership of a virtual body. [48]

4.1 Oculus Rift

Head mounted displays have been traditionally used in different professional fields as an example to train pilots, or soldiers to conduct military missions, in surgical processes, and in perception research. Jet pilots are depended on the augmented information the display provides, and surgeries demanding a great level of precision can be done easier guiding a machine in a designed virtual environment. In the last years head mounted displays have taken a big leap forward due to the recent technological innovations that enable cheap construction of satisfactory quality devices. [49]

An example of this progress is Oculus Rift which due to time of this report is still in its first prototype release, providing resolution of 640x800 pixels per eye [50], and horizontal field of view of 90 degrees, the vertical view area being 110 degrees. The display uses lenses to bend the light to magnify the field of view. Seen in the Figure 8, ' x ' is the field of view without the lens, where ' x' ' the field with the lens, ' d ' being the distance of eye from the screen, we can see that the lenses double the field of view. However, using lenses results as a distortion on the edges of the image, called as 'pincushion distortion'. In order to correct the image, an opposite distortion, called 'barred distortion' must be applied before sending the image to the screen. This process is called as a shader. [51]

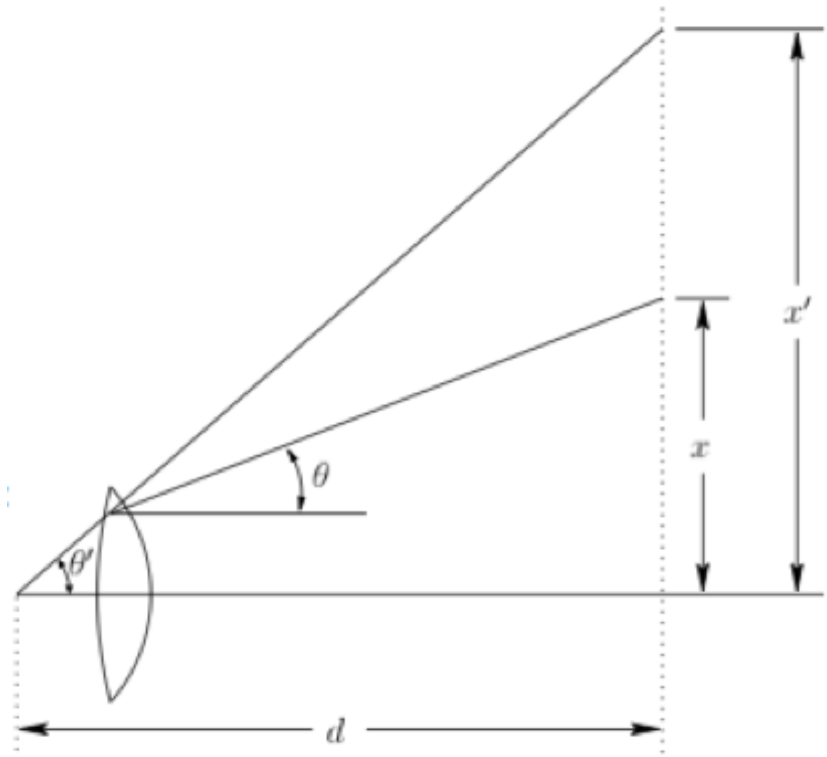

Figure 8. Oculus Rift. Figure from [51]

4.2. Cybersickness

Using virtual reality systems can cause cybersickness, that occurs with similar symptoms than in motion sickness. The symptoms, that can be eye strain, sweating, headache, disorientation, nausea and even vomiting, can start during the simulation or after the simulation, and can last for hours, even for days, depending on the duration of the virtual reality experience and subjective matters. The severe cases of cybersickness occur rather to pilots or other professionals who are training their missions in simulators and hereby are instructed not to control an airplane for the next 12-24 hours afterwards. [52, 53, 54]

Different theories have been suggested as the cause of cybersickness, the most accepted being semantical incongruent sensory data from visual and vestibular senses that results as the symptoms. As an example the participant might be immersed in a simulator in which he is using keyboard keys to control an airplane. His visual perception registers the movements of the plane steering, rotating and accelerating in the sky, but his vestibular system does not register the expected change as his is sitting head still on front of a computer. Therefore it is important a head mounted display to track the user's head position carefully and seamlessly. Another contributor to the sensory conflict is lag, that is a delay the head mounted display is interacting with the computer. Continuing the example, in a case where the participant is steering the plane to right but the visual feedback is given with a delay - causes confusion when the participants senses are trying to bind the data together. [55] The refresh rate of the given display should be at least 30Hz, otherwise flickering can notably contribute to cybersickness. Some individual factors have an affection to the vulnerability to experience cybersickness. Individuals younger than 12 years are more affected to cybersickness, in addition to women who have a greater tendency to get affected than men. [52, 56, 57]

4.3. Possible auditory techniques in ownership research

The role of auditory perception in body ownership experiments has not been researched; this is probably due to the fact that experiments using visual perception among haptics give plausible results and are easier to conduct. However, aural perception can create a strong telepresence sensation, as an example Turner et al. in their study in which the test participants were listening to different soundscapes and rating their feeling of presence. The participants could emigrate to the given soundscape and a strong sense of telepresence was created. The sensation required absence of other stimuli or interruptions; the immersion was significantly smaller if the test participants had to actively share their attention by describing the place they felt themselves being in. Closing eyes helps to create the illusion and can result to vivid imaginary of another place. [58, 59]

By using spatialized 3D sound to supply auditory cues it is possible to generate vivid experiences, such as ones that mix reality and past-reality and cause telepresence illusions. [60] When the visual perception is limited, we rely to auditory cues to determine the place where the sound is coming from. Binaural audio is a spatial technique that is commonly used to record or produce 3D sounds. The technique imitates human's natural audio filtering preferences as it is recorded by using a dummy head and a torso, or microphones that are used in ears. The sound is ultimately captured by our ears first filtering it in pinnae, skull and shoulders the sound waves interfering with each others, that is called as head related transfer functions. Ultimately the localization is done by analyzing the small temporal and volume differences the sound entering each ear. As individual corporeal proportions vary, the sound cannot be replicated as one would have heard it, therefore binaural mannequin's are based on average proportions. A small person listening to a recording made by a bigger proportion shaped mannequin will result as a loss of information as the person's brain has learned to decode different binaural cues, as the distance between ears, chest size, outer ear might can be very different. [61, 62, 63, 64] Another method besides a dummy to capture spatial aural information are binaural microphones, which are set on ears as earphones. [65] Instead of the proportions of a dummy head, the person conducting the recording gives the characteristics for head related transfer function. More similar the facial and bodily attributes of the person listening a binaural recording to a dummy head or to a person who conducted the recording with binaural microphones, the more authentic the experience is to listen afterwards.

5. DESIGN

Prior research has investigated different conditions in which rubber hand- and full body illusions can be induced, and the theories explaining the plasticity of body representation and suggested the most plausible origins of these. This report describes an experiment in which auditory and visual perception are being swapped between two people. It serves as a individual art installation but also contributes to cognitive science research by introducing auditory perception swap and investigating the outcome of swapping visual and auditory perception simultaneously between two participants.

Previously it has been presented that we can evoke an ownership to a mannequin body, or to a virtual avatar, to shake hands with ourselves and to feel being outside of our bodies. This design aims to allow the participants to step into the bodies of each others, and to look at themselves from the perspective of another person. It was acknowledged that completely life-like experience could not be conducted but with the given recourses and temporal constrains following experiment was designed:

The participants are wearing head mounted displays with cameras mounted on them to change their visual perception. The cameras mounted to the participant #1's head mounted display send the signal to the participant #2's screen. From the cameras on the participant #2's display the stream is played on the participant #1 head mounted display screen. Auditory perception has been swapped using binaural microphones which serve as earphones simultaneously. Using the same logic, sending audio signals is captured from the participant #1's ears to the ears of the participant #2 and vice versa. This setup sets constrains to the illusion as the head mounted display covers major part of the head - resulting the user seeing himself, not as he would naturally expect seeing himself in a mirror on the morning, but carrying the test equipment.

It was understood that the experiment carries multiple of variables thus the outcome of the experiment would be difficult to predict. Seeing yourself from another person's perspective as a thought play is abstract, but due to the evidence from prior research an out of body experience could be expected. The test analysis would be carried out with a qualitative analysis of the participants' experiments.

6. IMPLEMENTATION

Two Oculus Rifts were provided for the experiment, both of them being the prototype version. The design called for two web cameras to be mounted on each display to capture the vision of the user. The location of the web cameras was decided to set on the middle of the display, where the user's eyes are located. This location would give more natural experience than mounting a camera on top of the head of the user, a method that has been used in some related experiments. [4] The design calls the users to face each others, in which case it is more natural if the participants face each others from 'eye' to 'eye', also mounting the cameras on the Oculus Rift would preserve corporeal characteristics more having a camera on top of a head, that would also result the surroundings perceived in wrong proportions as the fixed view is around 10cm above the normal position. However, mounting cameras on the screen distorts the perceived spatial dimensions anyhow, since while being on the same line with the eyes, the vision is set 6 centimeters farther than normal fixed point of view due to the dimensions of Oculus Rift.

The chosen cameras were Logitech C910 and Logitech C920 web cameras, both of them providing resolution 1920x1080p, though the high quality being lost on the low resolution of Oculus Rift. Both of them have frame rate of 30 per second while using high resolution. The image proportion on the C910 is 4:3 where the latter one provides a wider view of 16:9. The cameras were tested using a checkerboard marker and produced no visible distortion. The cameras performed reliably, but poor performance was observed in low light and in heavy contrast conditions. If the subject would be front of a window on the daytime, the camera would focus and fix the exposure according to the subject resulting the person be visible, but the window overexposed. This kind of performance had to be obstructed from the test conditions.

6.2 Web camera mount

When an object is seen from a slightly different angle due to the inter pupillary distance, the brain is comparing two images and their similarities and small differences resulting into a 3D picture. Preliminary tests using one camera resulted in severe difficulties to perceive distances and therefore confusion. Hence, two cameras were set on each head mounted display to imitate the stereoscopic properties of human vision. [66]

In order to attach web cameras to the HMD, a mount was designed. The mount had to be adjustable due to the individual differences of inter pupillary distance. A small offset of the cameras would create a cross-eyed image. The mount had also a function to adjust the angle of the camera so that they both slightly tilt towards each other. In case the cameras lay flat without an angle, the stereoscopic image results to be focused on the infinity. By adjusting the angle of the camera, the cameras will intersect before infinity, causing objects that are near to float in front and the ones on the back to float behind; this method is called toed in. However, this 3D technique does not come for granted as it has similar limitations than our eyes, meaning that if the object is too close, the cameras will not intersect and the result image is out of focus. In sophisticated model the tilt level of the cameras would be automatic according to the focused object. It was not considered to start adding motors to control the cameras on this version of the implementation. The cameras were mounted vertically (tilted 90 degrees) to suit Oculus Rift's field of view better, that is provides larger vertical view than horizontal (640x800). (See Figure 9 and 10 for pictures of the mount)

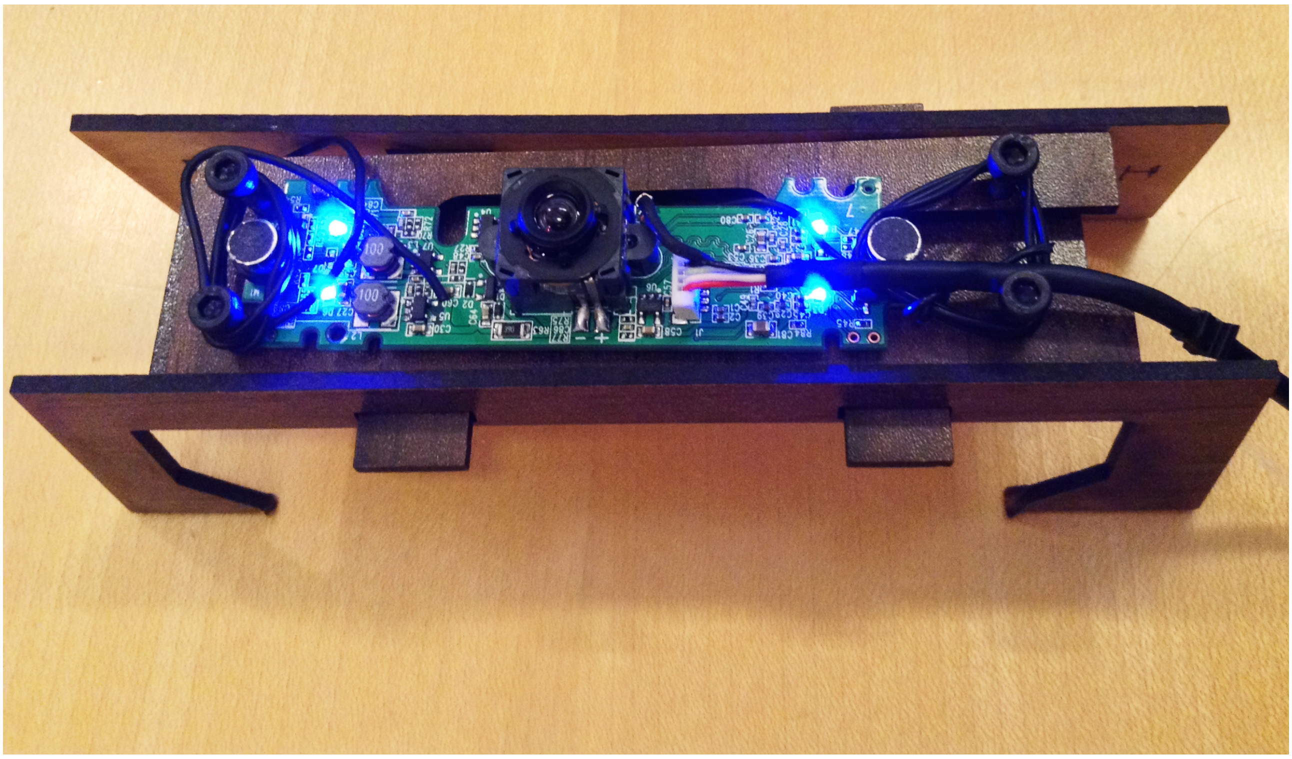

Figure 9. Web camera mount

A 3D model of the mount was designed on Autodesk Design 123D and printed with Makerbot Replicator Dual, but due to the inaccurate performance of the machine, this approach was ultimately discarded in favor of more accurate 2D design. A vector of the mount was designed on Adobe Illustrator, cut with a laser cutter and stitched together from four individual parts. The mount resulted to be fast, reliable and easy to adjust. The dimensions of the mount are made fit and tight according to Oculus Rift, in order to restricted involuntary movements. of the camera. By losing and tightening tension from screws that hold the web camera mount, the camera tilt level can be adjusted.

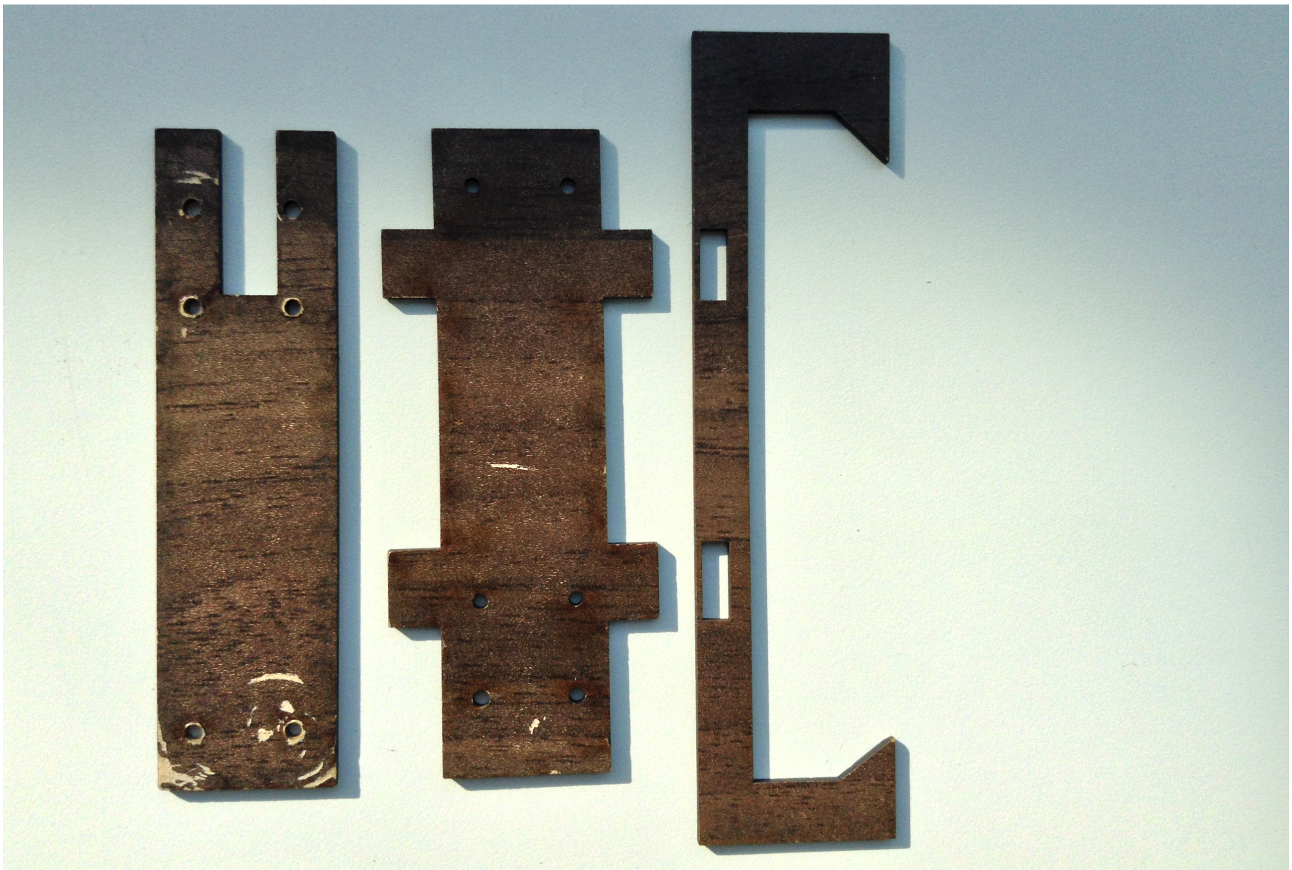

Figure 10. Web camera mount pieces

6.3 From the web camera to Unity3D

The web cameras were connected to a MacBook Pro running Unity3D code (program included in the attached CD). The code consists two cameras pointing to two different planes, to fill the field of view; one for left eye, second for the right eye. These planes are textured with web camera stream that is refreshing the image 30fps. (See Figure 11)

Head tracking was disabled, otherwise the user by rotating his head would navigate himself out from the stream view. The code resulted supplying live stream from two web cameras to an Oculus Rift. By cross-connecting the web cameras to a computer that is used as an output for the other Oculus Rift, resulted the other Oculus Rift to display the stream from the first. (See Figure 12 for the mounted web cameras on Oculus Rift).

Latency was noticed on the implementation and estimated to be in total around 60-70 milliseconds. Latency in Oculus Rift is around 50 milliseconds, and but the cameras responded fast resulting around 10 milliseconds. It was estimated that the amount of lag would not interfere with the experiment, as the participants would not have to move fast and the applied haptic stimuli could be made in slow pace.

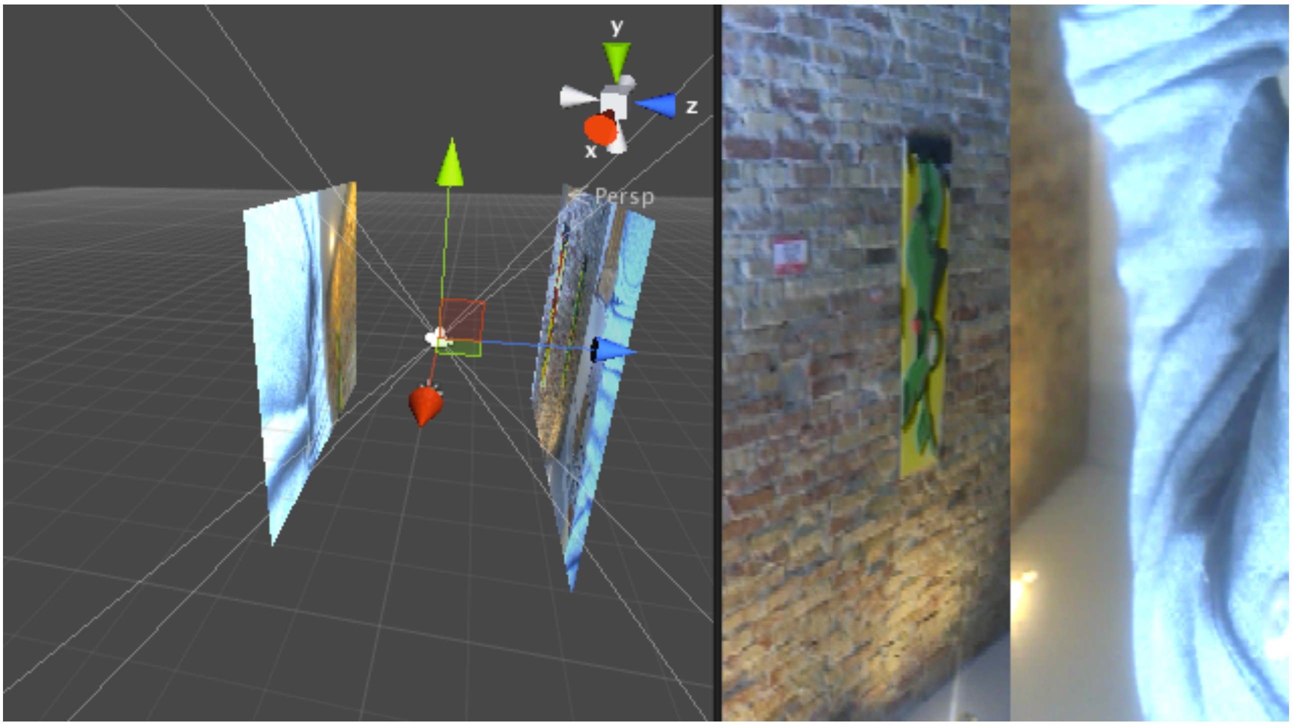

Figure 11. Unity3D camera design. On the right side is a stream from two web cameras pointing to different directions

The end result of the visual setup was satisfying in relation to the time and material constrains. In order to further develop the system, the implementation could have been done wireless, as in the current system there are two wires from the web cameras and one from Oculus Rift which are hindering free movement. The USB web cameras could be made wireless by using a USB sharing device and the Oculus Rift by making wireless HDMI device and batteries.

6.4 Visual pre-test

A pre-test of visual perception swap was conducted in a small, silent room, that was artificially lit in order to avoid overexposing from the window light. In total eight persons in four pairs were tested, the test participants being between 20 to 30 years old, 5 males, one female.

The pre-test was conducted using one camera on each rift, providing a monoscopic vision. This approach limits depth perception and field of view, but was obtained due to the time constrains. The experiment protocol was not strict during the pre-test, but usually started by the experimenter introducing the test equipment, informing that they are free to describe their experience during the test, and to stay completely still unless otherwise mentioned, whereafter they were set to face each others, and advised to wear the head mounted display. As the participants put on the display, a desktop image appeared causing confusion as the image seemed to be out of focus, since it was without a shader. Afterwards the experimenter started the program in the computer and the users were

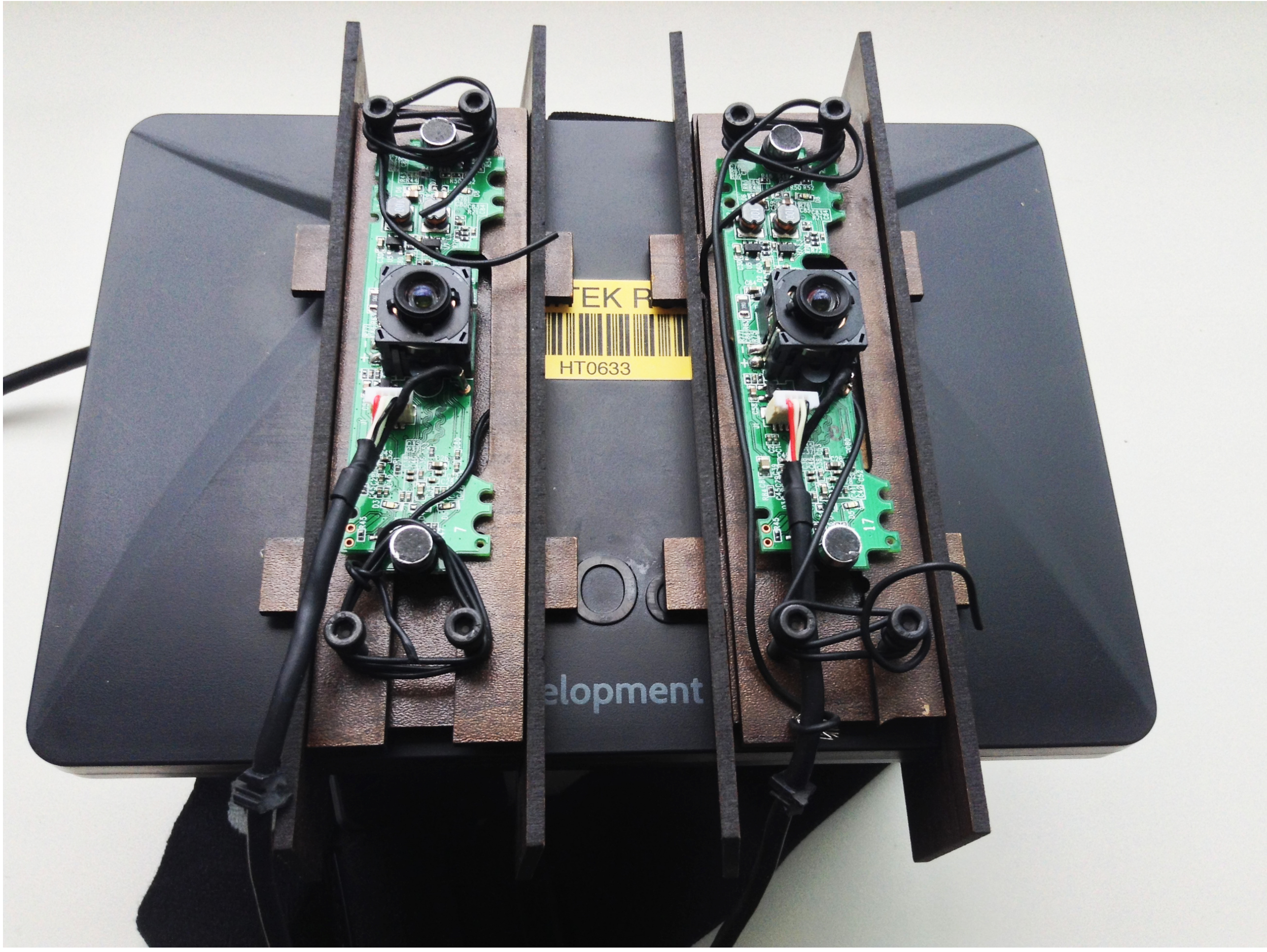

Figure 12. Two web cameras mounted on a Oculus Rift.

asked to perform various synchronous actions. The actions should be done simultaneously in order not to cause visual-proprioceptive incongruence, that would result hindering or breaking the illusion of ownership.

The participants were asked to shake each others hands, and to squeeze them arrhythmically, and also in another condition to look at their shoes while the experimenter was touching the tip of the shoe. However, asking the participant to look at his own shoe was not as easy as imagined, since visual perception was provided from another person's perspective: sometimes a participant would imagine watching his shoes in satisfactory angle, but the other person would not be able seeing his shoes. The view angle could be also totally off, resulting the participants being confused. (See figure 13).

Next, the participants were asked to face each others, causing the participant to see himself from the perspective of another person. Looking at each other, the participants were asked to touch their own head. This action caused confusion on the second pair, as the male participant touched his head after a laugh and with a delay, and the female participant did not touch her head, even though advised to do so for three times. After this the experiment was stopped and the participants were elaborating freely on the

Figure 13. The participants trying to see their own shoes.

experience, the female participant found it difficult to elaborate why she did not touch her head as asked to, and the male participant explained: “the first time when you asked me to touched my head, the first reaction was to crossing my hand over this thing (Oculus

Rift)”. These answers indicate proprioceptive displacement and confusion since such a simple task was found difficult. The third and fourth pair were advised to make a high-five on the end of the experiment, which was proven to be very difficult, since the fact that depth perception was non existent due to the lack of stereoscopic view. None of the participants informed about cybersickness during or after the test, but all of them reported confusion of some degree. Overall, the visual pre-test resulted proving the concept working technically well, but also encouraging to develop stereoscopic view for the main test.

6.5 Auditory implementation

The auditory perception was swapped by using two pairs of Roland CS-10EM binaural microphones, which work simultaneously as headphones. The microphones are electret and omnidirectional, and capture frequency range from 20hZ to 20khZ that is the average hearing range of a human. Two Zoom H4n recorders were used to supply needed 3-5V for the microphones to work. The microphones were cross connected to the recorders, making one recorder to playback what another monitored and vice versa. (See Figure 14 of the auditory devices) [65]

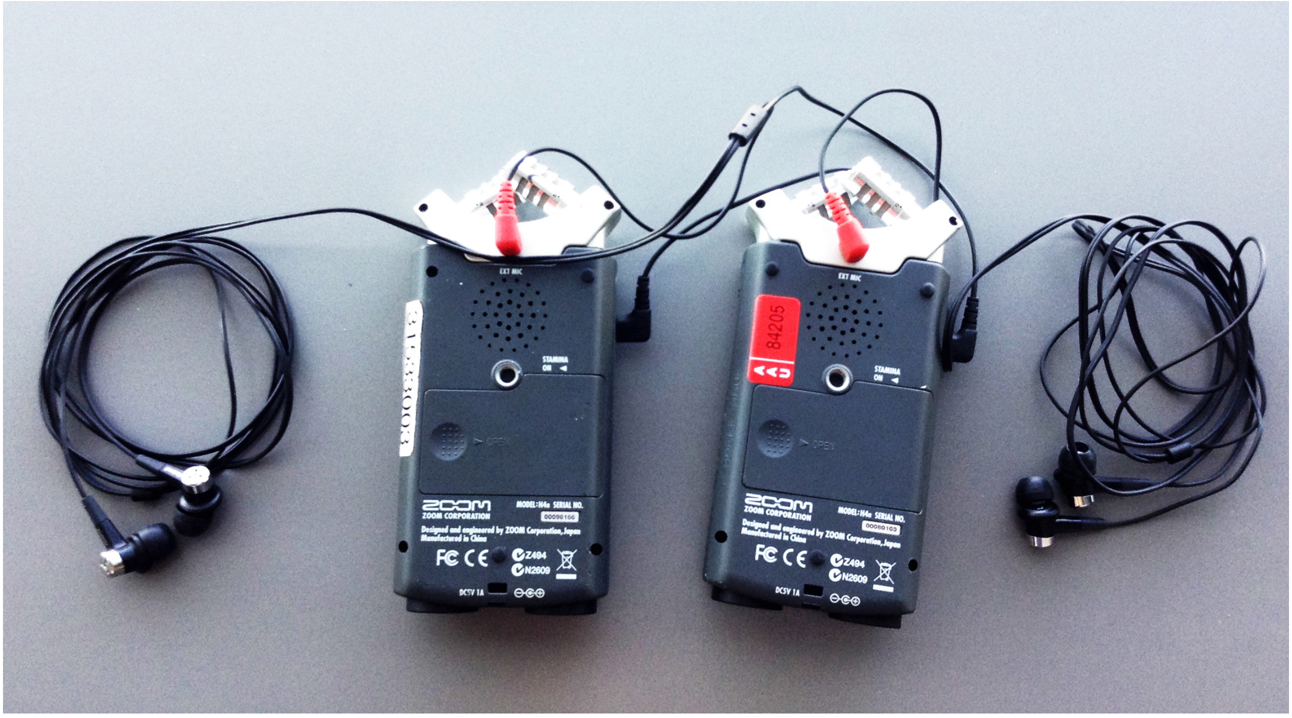

Figure 14: Binaural microphones are cross-connected to Zoom H4n Recorders

The performance of the microphones and the concept of swapping auditory perception was tested using six persons, aged between 20-30 years with normal hearing, all male and students. The test was conducted in the same room, that was used for the main tests. The test participants were asked to sit on a chair and face each others, to wear microphones whereafter the they were switched on. The test participants were informed to close their eyes and to point to the direction of the heard sound with their finger. The experimenter generated auditory cues around the participants' head. Afterwards they were asked to evaluate the experience.

The results indicate that the binaural microphones blocked the surrounding sounds better than expected, emphasizing the incoming sound coming from the other participant's binaural microphones. The volume level was set a little bit higher than a normal hearing in order to maximize the sound substitution. As an example, when the experimenter whispered to participant #1's ear, the participant #2 heard it, causing both of the participants experience the experimenter being in their personal space, but the #2 having even stronger sensation.

The sound localization was accurate with few expectations. When the sound was generated front or top of the participant's head, the participants could not properly locate the sound source, pointing often behind their heads instead. This mislocalization was probably due to the natural difficulty of humans to distinguish sounds front of them, since the distance between the sound source and both ears is merely the same, hence the temporal difference is difficult to calculate. The differences of the participants' body and facial structure matter also to the spatial recognition, but did not seem to play significant role on these tests. Still, taking in consideration the physical differences in the participant's body and head and the limitations of the chosen binauralization technique, the auditory perception swap cannot be mimicked one to one. However, results from the pre-test were positive as they generated a strong experience even though these limitations.

6.6. Conclusions from the pre-tests

Due to the experience from the pre-tests, the main test protocol was formed to limit the movements by the participants, including simultaneous movements with the other participant. As Slater presented, [17] incongruent movements would hinder the possible illusion and coordinating the participants to make the exact same movements would be difficult. Ehrsson also presented [27] that active movements did not result to a stronger sensation of ownership.

While the test participants were handshaking each others, and looking at their hands, the field of view hindered them to see their own face. The view was usually the other participant's hand coming out from their point of view, grabbing their own hand, following to their torso. This view resembled the condition on Ehrsson's body swap [4].

The participants looking at their own shoe was ultimately dropped as well, even though the visuo tactile stimuli seemed to work well, since the camera setup made it difficult the participants to see their own shoes, often resulting to a confusion when the experimenter was trying to adjust their view. Same issue was when considering the participants to look at their own body; the cameras were located further away from the normal location, making the participant unable to catch the natural angle to look down. Also the test equipment cables hindered free movements.

7. TARGET GROUP

The primary target group was set to 20-50 years old people, all genders, from WEIRD (Western, Educated, Industrialized, Rich, and Democratic) societies who were not visually or aurally impaired. The target group can feel comfortable during the tests as they are used to interact with new technologies. For the experiment, twenty healthy volunteers were recruited. 11 males, 9 females, mean age 27 years. Eighteen participants faced the protocol while the first pair had only the third condition.

8. TESTS

The purpose of the test was to understand the sensations arousing when seeing oneself from another person's perspective - should we feel ownership more to ourselves, or to the person whose visual and aural perception we are using? Another purpose for the test was to prove the concept, so that it could be used for different projects and to developed further. The experiment was conducted in a small room with fixed light in order to avoid over exposure from window. Test equipment was set on a table, consisting: two Oculus Rifts, two USB hubs, four web cameras with mount, two binaural microphones, two MacBook Pros and two Zoom H4n recorders. The web cameras were pre-mounted to the Oculus Rift to the average inter pupillary distance 6,3cm. The tests were recorded using a video camera for analysis purposes [66].

8.1 Test Protocol

The participants were introduced to the test equipment and asked to sit down facing each others on distance which just allows them to handshake each others. Participants were advised to wear Oculus Rift and binaural microphones, and asked not to move unless by the experimenter's note. The participants were free to elaborate on the experience between the conditions and during the condition after haptic stimuli had been supplied for around 15 seconds. The stimuli was continued up to 60 seconds during the elaboration and test condition.

First, the participants were asked to shake their hands, to hold them, and to look at their hands. The experimenter made brush strokes on their hands simultaneously in mirror positions of their hands, so that both of the participant's would have a similar view of their hand and the brush. The strokes were slow, from one to two seconds and few centimeters long, moving first towards hands, and back towards shoulders.

After a minute of stimuli, on the second condition the participants were guided to face each others, and brush strokes were applied on the middle of their forehead or throat for average a minute.

In the last condition the experimenter was talking and making sounds with the brush around the participants and asking them to evaluate on how they felt, particularly about embodiment.

After free elaboration and possible specified questions, the participants could take the test equipment off and were asked to elaborate on the whole experience. Afterwards, some of the participants were asked specified questions without the other participant being present.

9. RESULTS AND DISCUSSION

The implementation performed generally well in the test, but required usually 5-10 minutes of preparation for both test participants. The average inter pupillary distance worked for most of the participants, but some adjustments were made to correct the camera's tilt angle. It was understood that if the participant had short hands, their vision would be out of focus as the toed in cameras would intersect too far away. The camera angle was increased for optimal focus. In two test situations one of the computers started to ignore video feed from one of the web cameras, supplying a monoscopic vision to the participant. The reason for this was not fully understood, but assumed to be a camera or computer hardware problem. The problem was solved by rescheduling the test and restarting all the test equipment. Typically the experience of seeing yourself from another person's perspective was defined as "confusing" and "weird", some participants found it difficult to describe what was happening, due to the fact that "there is multiple things going on!". All the test conditions generally aroused strong statements and sensations often verbalized in such statements as 'this is so... wow!", "this is freaky! oh my god!", "super weird", "strange".

9.1 Holding hands and swapping their ownership

The first condition (See Figure 15), having hands in handshake position the experimenter brushing them, created clear sensations of the participant's hand being their own in 16/18 cases. The sensation started fast, almost immediately for some participants, describing the experience as : "I don't believe in most of the time, but my hand is on the other side!", "It feels like I'm watching my own hand!", and "her hand is like my hand...". Few participants were describing the sensation happening in phases such as: "This is starting to feel more

Figure 15. Condition one.

and more my hand". Even though many of the participants' had different characteristics such as tattoos, red nails, big hands, small hands, the participants felt the haptic stimuli being applied to the other participant's hand instead their own hand, that was clearly recognizable and in their field of view. After all the tests had been conducted, one last experiment was made on the fly. In this experiment the participants were holding their hands on handshake position, the experimenter brushing them, but suddenly after thirty seconds stopped brushing one of them and continued brushing the other. This gave powerful sensations as they were not able to feel anymore with the hand they had embodied, even thought they saw the same stimuli still continuing on their hand.

The results from the first condition demonstrate that it is possible to swap the ownership of two participants' hands. In 16 cases out of 18, strong statements of the established ownership was given. In the two cases ownership might have occurred but remained inconclusive due to the participants' restricted verbal elaboration. This test condition resembled one that Petkova and Ehrsson conducted [4] in which the participant could see the experimenter's hand as his own. Their experience differs in a way that the experimenter herself could not establish an ownership to the participant's hand, the illusion being one-way. Hereby, it can be presented that two persons can swap ownership of their hands simultaneously by providing them first person's perspective of each other's vision, and haptic stimuli by brushing simultaneously their own and the other participant's hand with slow strokes. The illusion occurred often fast, less than in ten seconds, while congruent visuo-tactile stimuli creates a percept that the other person's hand is belonging to herself. Other constrains here are that the embodied hand must be corporeal and that it must be perceived from the first person's perspective. As expected, the gender or the characteristics of the hand did not seem to matter whether there could be established ownership or not, and as well as the other participant's hand, the hand could have been a fake hand. Low resolution of the visual perception does not seem to hinder the illusion. These results could be solidified by using galvanic skin response as an objective measure of the illusion, in such a case that the embodied hand would receive threat. Also, as preliminary tested, by suddenly stopping stimulating one of the hands, while continuing the stimuli on another, created a confused feeling - this sensation could be explored further and possibly measured whether it elicits measurable emotional responses. Another condition to solidify the results would be to use asynchronic stimuli to measure whether the ownership would be established in this condition. In addition, a traditional questionnaire could be used to measure the ownership. Auditory perception seemed to play a minor factor in this condition, as the experimenter was in the middle of the two participants and didn't make any auditory cues on the range of the microphones.

9.2 Looking at myself and wondering where I am

In the second condition, the participants were first facing each others, hence looking at themselves. (See Figure 16 for a picture of condition two) Four of the participants described the sensation that they became strangers to themselves; such as "The strangest thing: I don't know if I would say that I was him, but definitely I did not feel it was not me I was looking at. It felt like it was somebody else. It was really weird", reported a male participant, and likewise a female participant described: "I feel like I am watching another person but I still see myself talk". Other descriptions of this sensation was that they felt like seeing themselves in television, or compared the situation to a sensation when hearing yourself talking in an audio recording; you know it is you, but still it sounds different. Eight participants described that they felt being embodied to somewhere else, watching themselves from "outside" or embodied into another body; "It feels like I am a different person looking at myself", or being embodied to two bodies at the same time; "I felt like.... my body in myself but I felt I was another person... like i knew it was me i could see but i also know that i was sitting here. Like two me's!", describe a female participant. One participant specifically pointed out the changed when haptic stimuli was applied: "I feel like I'm looking myself from a mirror.. but when you touch it in a head it's not like in a mirror".

In other cases the sensation of looking yourself from the other person's perspective was so full of confusion that the visuo-tactile stimuli was not specifically stressed in the elaboration. What worked with the stimuli for the hand was not completely fit to the head. Some participants compared this condition to the previous one stating that the sensation on the first was stronger. The second condition caused more overall confusion, limiting the attention given to the visuo tactile stimuli. The participants were describing that "there are multiple things going on!", that hindered the needed focus to create a stronger embodiment. As the induction of the ownership can be based on prediction and expectation of the repetitive stimuli, continuing the stimuli for five minutes could have done changes to the sensation as the participants would have gotten more used to the current view. In the given condition the participants' brains were trying to make coherent percepts from the large amount of data that was a result of multiple different mechanisms and variables.

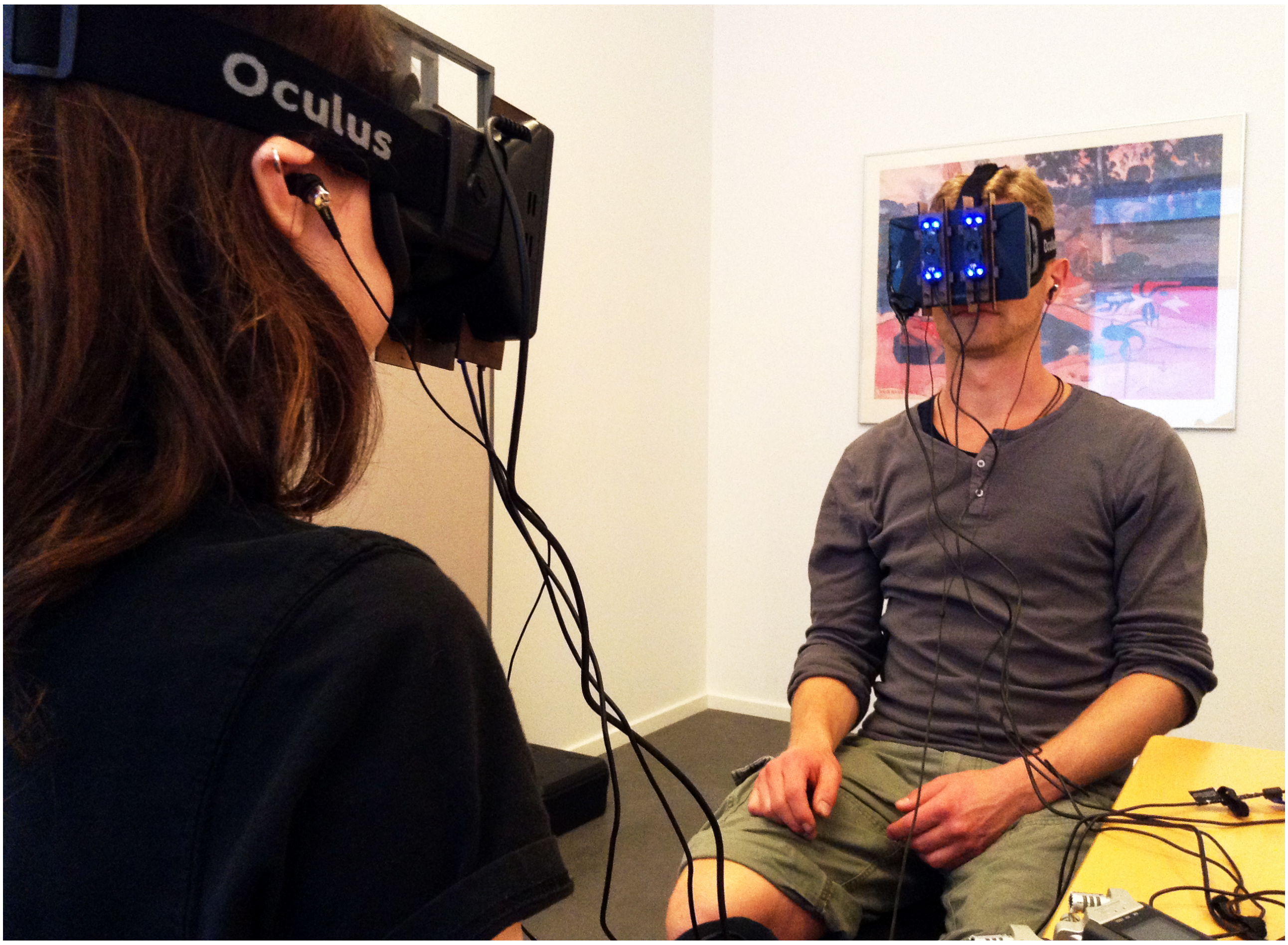

Figure 16. Condition two

However, if the person established an ownership of being outside of his body, it could be easily interrupted by the other person moving a little bit, causing the visual perception to change, creating conflicts between visual perception and vestibular system as the person himself is not moving. Another persisting conflict is visual perception from the first person's point of view and the visual feedback itself in which the user sees and recognizes himself. In four cases the conflict caused the user refuse to recognize himself. This could be related to different stages establishing an ownership to a rubber hand, that progresses from losing ownership to own hand to establish an ownership to the substitute hand; [13] similarly establishing ownership to a substitute body could progress. Hence, it is possible that the state would have changed if the tactile stimuli would have been supplied for an extended period of time. The second condition supported the view that out of body experience could be conducted by chancing visual perception of the participants and stimulating them in synchrony on forehead or by another stimuli on a similar setup. However, most of the participants could not verbalize changes in their body ownership, hence the condition should be redesigned to limit the amount of incoming percepts and solidify the results with a detailed questionnaire and objective measures.

9.3 Looking and hearing myself from someone else's perspective

In the third condition, the participants were looking at each others and the experimenter was talking and making sounds around their head. As the pre-test results indicated, auditory swap can create a strong sensation alone. In this condition, while the test participant was looking at herself, and the experimenter talking behind her, the other participant had ‘weird‘ sensations since the she could not bind the visual and auditory perception; as one participant described: “Specially the sound... When you were standing next to Mikkel, the illusion that you are here behind me was really strong” and “It's like hearing your voice talking inside my head.. so strange. It's weird that you could hear it, but not to see it” and “this is so weird, it's like you're right next to my ear but you are not”. Even though the participants could recognize the location of auditory cues accurately, they could not describe whether it had an effect to the embodiment or not. A participant described the sensation: “When I heard the sound it was like exactly you were standing behind me. I knew it was myself (what i saw) but when I heard the sound behind me I didn't consider him being me”. Also the auditory condition was never pointed out specifically on the evaluation after the test.

From the results of the third condition it cannot be concluded that auditory perception swap would have made the feeling of being inside another body stronger. The location of the auditory cues was recognized accurately and the condition created immersive experiences. In case of exploring body ownership, the auditory swap does not seem to play a significant factor, due to the dominance of visual perception. However, the auditory swap can enhance the immersion. Swapping auditory perception could be used to research body ownership on blind. Ehrsson experimented that the somatic rubber hand illusion does not work with blind, probably due to limited multisensory interaction that is developed on early age. [25] Due to the enhanced role of auditory perception of the blind, auditory swap could result to very interesting results, possibly an embodiment of a different person.

9.4 Adapting to the condition requires cooperation

The participants had to be adjusted by the experimenter to the current condition; to face their hands or each others - even though there was sometimes small mis-setting due to the difficulty of maintaining exactly the same head position over time, sometimes the participants by reflex tried to correct their vision, resulting to confusion. This was described in many occasions: “It's the strangest thing, you have to continuously remind yourself that I'm not controlling my head” and “The most confusing was to try to turn yourself to some other place and then realize you are the person sitting over there... but you start moving first even thought you know you are reluctant to doing it because you know you self are there but it doesn't take long to get there - it's a reflex”. While one participant tried to adjust his vision, the the other one carried the consequences by getting a misplaced view. From the results of pretest and these miscalibration feedback some of the participants wanted to play with the installation afterwards. The challenge to adapt to the system that one is not in control of his own vision nor hearing created a mutual task that encouraged the strangers to interact with each others in a situation that is equal strange for both of them but requires extensive cooperation. Hence, the implementation has uses in art and free exploration.

10. CONCLUSION AND FUTURE WORK

In this report a state of the art of body ownership illusion and rubber hand illusion has been presented and the reasons behind the malleability of body ownership have been discussed. The rubber hand illusion is often explained as a result of multisensory integration of visuo-tactile and proprioceptive signals and with similar methods a full body ownership illusion can be inducted. Furthermore, a prototype was created and experimented to understand a concept of meeting oneself from another person's perspective, and a method to change auditory perception between two people is presented. The experience was created by mounting stereoscopic cameras to a head mounted display and using binaural microphones which worked simultaneously as headphones. The point of view video stream from the first participant was sent to the second participant's head mounted display, as well as the input from the microphones which were placed in the ears was sent to the second participant's ears. Similarly, the first person received the audio-visual stream from the second participant. The test was experimented in three conditions: in the first the participants perceived themselves swapping their hands, in the second condition the participants could face themselves from another person's perspective, where as in the third condition the auditory swap was examined in more detail, but the results remained inconclusive. The dominance of visual perception possibly suppressed the sensations from the auditory swap in the main test, but among the results from the pre-tests which presented immersive sensations, the method could be further investigated and possibly used in art installations, or to provide new methods to research body ownership on blind participants, since both auditory and visual cues are reference elements in their fixed locations in our body. As like first person's point of view from the fixed location of our eyes contributes sighted people to decide our current location, on the blind this could be more depended on the fixed place of our ears and their perception

The test was experimental and proof of a concept, which resulted in new approaches to examine body ownership and as a concept for art installations; for example it could be interesting to develop the installation wireless and to set two people to interact with each others in a situation that they have a mission to accomplish but they have swapped their visual and auditory perception. This would require strong cooperation that would break barriers between the participants, but also to challenge their skills of being able to adapt to new situations and to improve their communication. Also, an art group, Be Another Lab created an installation on January 2014 in which two participants of different gender see their bodies from each others point of view using an implementation resembling the one described in this report about swapping visual perception, although theirs installation being monoscopic. However, as their project was not a scientific study, and no results were published, the project remains as an inspirational example of different uses of similar installations. [67]

The presented three conditions caused strong reactions on the participants, but understanding why the certain reaction occurred is more difficult. The relationships between multiple processes in the presented conditions are complex, but they arouse seemingly from multisensory interaction - however, specially in the second condition, in which the participants saw themselves from another persons perspective, the participants were confused, as if they could not solve some of the conflicting processes. Basically the condition could be examined by using a stereoscopic camera to film the participant from distance as no corporeal hints were given in this condition, but in this case the sociality of the experiment would have been diminished, and also it would have limited the test to be performed by one participant at the time. In addition, the second condition could be improved by applying visuo-tactile stimuli for an extended amount of time, but also by the participants putting their hands on each others shoulders and actively start triggering the illusion by synchronic hand movements. This would cause a visual sensation that arms are reaching out from the participants body to the shoulders of the person himself. From the first condition it can be stated that the sensation from first person's perspective is enhanced while the body is perceived - this would probably result to actual embodiment, not to a sensation that the participant feels being 'somewhere' as there was no self-corporeal hints in the second condition. The condition couldn't be improved on the scope of the project, neither could have been the implementation suitable for it, since in the case that participants would have put their hands on each other's shoulders, the distance between the two participants would have been too short, resulting to an out of focus image in the head mounted display.

The participants were elaborating freely on their sensations during the experiment which created immersive experiences that could be further solidified with objective measurements and in improved conditions. Due to the test equipment limitations and time constrains no further tests were conducted such those that could include measuring chances in galvanic skin response or an asynchronic visuo-tactile stimuli test conditions. In this experiment asynchronic visuo-tactile stimuli was given only in an extra condition for two participants, this did not cut the illusion of the ownership, but aroused feelings that proved that ownership had been created as the participants described a loss of touch, when the participant's hand was stimulated. Also, in an ideal condition the participants would perceive themselves without a head mounted display covering half of their face; tests like this could be conducted by using virtual reality techniques.

Overall, a low resolution display and a given narrow field of view with multimodal stimuli can create sensations that encourage an individual to interception and self observation, that is an ability that truly defines humans. Embodiment research can be applied to the fields of telepresence and telerobotics. Since we already can move robotic limbs, and control whole robots, controlling them with a feeling of ownership upon them is a process that purely is designed for our brain. If we can achieve an equal strong embodiment into another person or into a virtual avatar in a virtual world, we can have more methods to explain the origins of bodily processes that affect our actions and cognitive processes as they can also serve as a research tool in different disciplines such as in social psychology and psychophysical experiments. They can also provide us information on distorted body self-perception, as in cases of anorexia nervosa, and to provide ways to reduce racisms and prejudgement. Conclusively, body ownership research provides valuable tools to learn and experiment more about the questions that scientists and philosophers have been thinking since humans developed the skill of a self perception.

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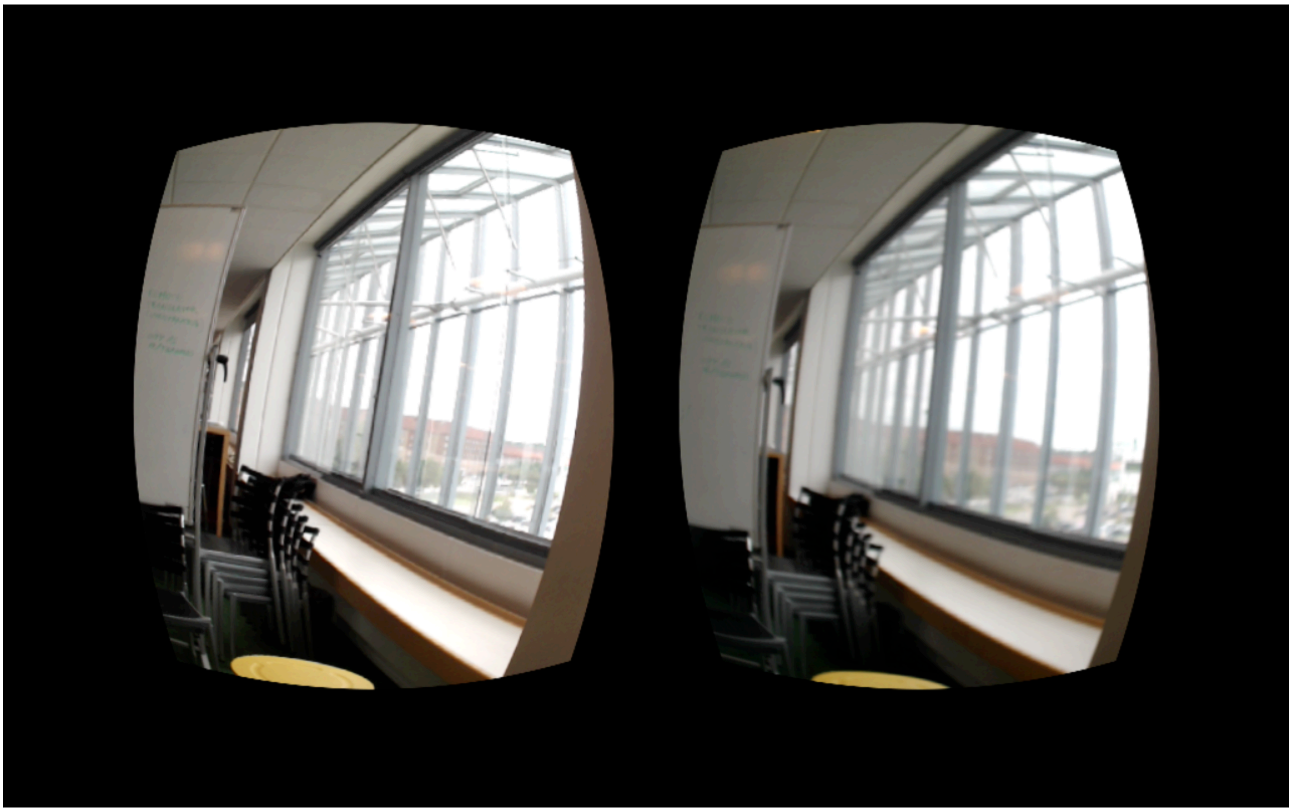
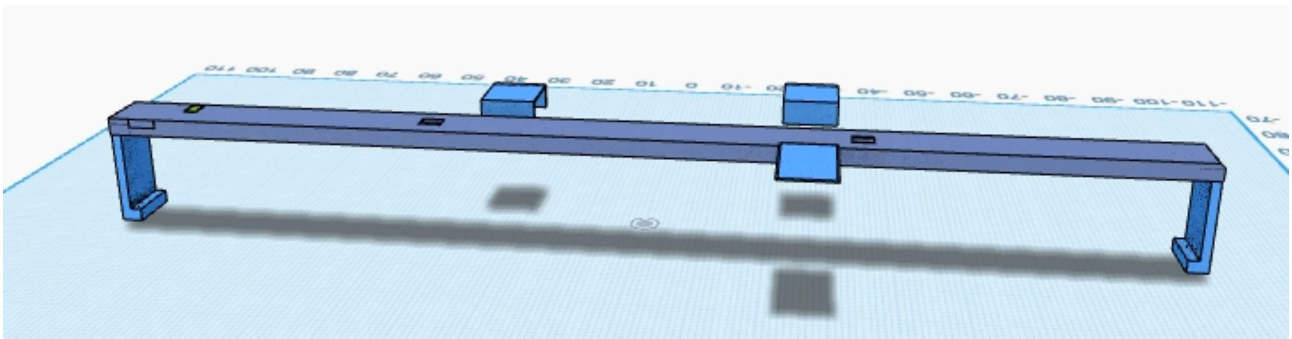
12. APPENDIX



Appendix Figure 1. A view from Oculus Rift. The image is split for two eyes and has barrel distortion.



Appendix Figure 2. A 3D model of an adjustable web camera mount. 3D models were disregarded.