Universiteit Utrecht
Masterprogramma Psychologie, Neuropsychologie

THESIS

Comparing bodily illusions: the rubber hand illusion and the mirror illusion

M.C.A. Winterman, 0414425
20-02-2008

H.C. Dijkerman & M.P.M. Kammers

Comparing bodily illusions: the rubber hand illusion and the mirror illusion

M.C.A. Winterman

Department of Psychology, University of Utrecht, Utrecht, Netherlands

20 February 2008

Supervisors: M.P.M Kammers, H.C. Dijkerman

Abstract

Different mental representations of the body have been proposed by different researchers. A common distinction between body representations is between the body image (perceptual responses) and the body schema (motor responses). In this study the difference between these two representations is investigated by using two bodily illusions, the rubber hand illusion and the mirror illusion. In the rubber hand illusion subjects view stimulation of a rubber hand while feeling synchronous stimulation on their own hand, which may lead to the feeling that the rubber hand is part of their own body. In the mirror illusion subjects view stimulation of the reflection of their own hand while feeling synchronously stimulation of their occluded other hand. Subjects may feel that the reflection of the seen hand is their occluded hand. Because previous studies yield different results (the mirror illusion does seem to have influence on reaching responses, and the rubber hand illusion does not), in this study both illusions are compared. After stimulation (synchronously or asynchronously inducing or not inducing the illusion, respectively) in one of both illusions subjects performed perceptual and motor responses, which are argued to be based on the body image and the body schema, respectively. Results showed that inducing the illusion influences the perceptual response (perceived location) of the stimulated hand significantly more than not inducing the illusion. The rubber hand illusion and the mirror illusion differ significantly in the perceptual response, with the mirror illusion having a stronger effect. Inducing the illusion does not influence the reaching movement with the right stimulated hand towards the left hand, and the type of illusion does not have an effect on the reaching response. Both illusions seem to influence the body image, and not the body schema in this particular set-up.

Keywords: Rubber hand illusion; Mirror illusion; Body image; Body schema; Perception; Action

1. Introduction

We need a representation of our body for a whole range of everyday behaviours. If we do not know the position of our body parts, or the properties of our body (size, shape, etc.), we can not make accurate movements and actions. Different mental representations for the body have been proposed. One of the most well-known distinctions is that between the body image and the body schema, but the definitions of these terms differ between researchers. Gallagher and Cole (1995) for instance describe the body image as a system of perceptions, attitudes, and beliefs pertaining to one's own body. According to Paillard (1999), the body image also involves knowledge about the position of body parts with regard to each other, i.e., it includes all the information one needs to make judgements about the properties of

the body (identification). In contrast, the body schema is described by Paillard (1999) as a system of sensorimotor capacities that function without awareness or perceptual monitoring (action). According to Gallagher and Cole (1995), the body schema represents a map of the body based on the information necessary to make movements with the body (e.g. position and posture). If we unconsciously make a mistake in either the judgement of the properties of our body, or the position of our body, this would have consequenses for our actions (De Vignemont, 2005).

The distinction between body image and body schema is based on a double dissociation in neurology (De Vignemont, 2005). Patients with neglect (with a lesion in the right hemisphere) pay no attention to the left side of their body. For example, they wash and shave only the right side of their face. This seems to be the result of a distortion of the body image, because these patients have a distorted perception of their body. Another example of a distortion of body image can be seen in patients with autotopagnosia. These patients are unable to perceptually localize body parts, but correctly name the same parts when pointed at by the examiner (Sirigu et al., 1991; Buxbaum & Coslett, 2001).

In contrast, in deafferented patients, who do not receive tactile or proprioceptive information below the neck, the body schema seems to be distorted and replaced by a highly developed body image. These patients are not able to move if they do not observe attentively what they are doing (Gallagher & Cole, 1995). Apraxia is another likely example of a disturbed body schema (Sirigu et al., 1995). Patients with apraxia have difficulties with executing learned, purposeful movements. Anema et al. (2006) describe a patient with a distorted body image (left media infarction), and a distorted body schema (lacunar infarction of the left thalamus), respectively. The patient with the left media infarction could not use tactile information to guide movements towards his own body. The patient with the lacunar infarction of the left thalamus lost the ability to localise tactile information on a visual representation of the hand. These studies could be evidence for the dissociation of the body image and schema, and their underlying brain structures.

Body representations have been studied in healthy individuals using bodily illusions. Two of these bodily illusions are the rubber hand illusion and the mirror illusion. In the rubber hand illusion (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005) the subject's hand is hidden, while he sees a rubber hand in front of him. The real hand and the rubber hand are stroked synchronously, and after

some time the subject feels the touch of the brush not on his real occluded hand but on the viewed rubber hand. This leads to a distortion of the location of the real hand towards the rubber hand. When subjects were asked to point to the stroked hand with their other hand, their movement was displaced towards the rubber hand. However, this reaching movement is not really a ballistic movement, it is more dependent on the 'knowing where' than 'knowing how to get there' principle (Paillard, 1991). The reaching movement is more a type of perceptual reaching, which is thought to be dependent on the body image. Asynchronous stimulation of the rubber hand and the occluded hand or incongruent posture of the rubber hand and the own hand abolish the illusion (Armel & Ramachandran, 2003; Schwoebel & Coslett, 2005; Tsakiris & Haggard, 2005; Lloyd, 2006; Constantini & Haggard, 2007). The abolishment of the illusion when there is an incongruent posture of the rubber hand and the own hand suggests that knowledge about the position of the body parts plays an important role in the illusion.

Most subjects feel a sense of ownership towards the rubber hand. This suggests that attachments to the body, such as prosthetic devices, can become incorporated into the representation of the body (Gallagher & Cole, 1995; Ehrsson, Spence & Passingham, 2004; Ehrsson, Holmes & Passingham, 2005; Ehrsson, Wiech, Weiskopf, Dolan & Passingham, 2007). They can affect the perceptions pertaining to the body, and the movements made with it.

According to Tsakiris and Haggard (2005), subjects feel only the position of the synchronously stimulated finger drift towards the rubber hand, but there is a spreading gradient of the rubber hand illusion to the unstimulated fingers. However, when the index finger is moved actively by the participant the proprioceptive drift affected the whole hand (Tsakiris et al., 2006). The movement of the body (efferent information) plays an important role in the sense of ownership. According to De Vignemont (2007), the sense of ownership is given by the body schema. But this does not explain why the rubber hand illusion also takes place when the fingers are not moved actively. The body image seems to have a role in the sense of ownership as well.

A recent experiment with the rubber hand illusion did show a distortion of the perceived location of the real hand, but did not show a displacement of the reaching movement (Kammers, De Vignemont, Verhagen & Dijkerman, submitted). Action does not seem to be affected by the proprioceptive drift (i.e. the distorted perceived location of the hand) towards the

rubber hand. This could be evidence for the dissociation between the body image and the body schema. The perceived location of the occluded hand is shifted, which is dependent on the body image. However, the reaching movement, which is thought to be dependent on the body schema, is not displaced towards the rubber hand. The illusion seems to influence the body image, but not the body schema.

Vision is mostly the dominant type of information used for localization of the body parts. (Van Beers, Wolpert & Haggard, 2002). In case of conflict between the different types of information (vision, touch, proprioception), the reliability and intensity of each of these types determines which one predominates. During the stimulation of the occluded hand and the rubber hand, vision is the dominant type of information. The subject sees the rubber hand being stroked, while feeling the stroke on the occluded hand synchronously (tactile information). There is no interfering proprioceptive information available, because the hand is not being moved. Only vision and tactile feedback can be used to localize the hand, in which vision seems to be dominant. This explains the distorted perceived location of the occluded hand. On the contrary, the reaching movement can not be observed visually. During this movement new updated proprioception is the dominant type of information. This might explain why the reaching movement is not displaced towards the rubber hand in this illusion.

In contrast, the mirror illusion has induced distortions in reaching movements (Holmes, Crozier & Spence, 2004; Holmes & Spence, 2005; Holmes, Snijders & Spence, 2006). In this illusion one of the subject's hands is hidden behind a mirror, while the other hand is placed in front of the mirror. The subject sees the hand in front of the mirror reflected in the mirror. The illusory reflection of the hand lies on a spatial different location than the occluded hand. When both hands are moved actively and synchronously by the participant, the subject feels that the mirror reflection is identical to the real occluded hand. This leads to a distortion of the location of the occluded hand towards the illusory hand. When subjects were asked to reach to the seen hand with their occluded hand, their movement was displaced towards the illusion hand (Holmes, Crozier & Spence, 2004). In contrast to the rubber hand illusion, participants moved their hands actively during the inducement of the mirror illusion. When moving body parts actively there is additional proprioceptive information available. One might argue that this can be available to the body image and the body schema. The body image is

more influenced by vision than by proprioception, but for the body schema proprioceptive information is thought to be weighted more heavily. This could be the cause of the displacement for the reaching movement in the mirror illusion, and not the rubber hand illusion.

The differences between the rubber hand illusion and the mirror illusion have not been investigated yet. First, the type of stimulation used is a significant difference between both illusions in current research. It is unclear whether the perceptual responses as well as the motor responses differentiate for both illusions, when the same type of stimulation is used. The second difference between both illusions may lie in the sense of ownership. In the mirror illusion the illusory hand is the reflection of the participant's real hand. In the rubber hand illusion the illusory hand is a rubber hand, which is less visual similar to the real hand. A sense of ownership of the rubber hand is necessary for the illusion to occur. It is important to investigate these differences to draw meaningful conclusions from both illusions in healthy subjects. Results of this study could be evidence for the distinction between the body image and the body schema in healthy subjects.

In this study the difference between these two illusions is investigated by making both experimental set-ups as similar as possible. First, in this study both illusions are inducted passively, by stroking the subjects' hands with brushes, which has not been investigated yet in the mirror illusion. Second, in both illusions perceptual and reaching responses are compared.

The first hypothesis is that in the rubber hand illusion as well as in the mirror illusion the perceived position of the real hand is closer to the illusory hand than it actually is. Both the rubber hand illusion and the mirror illusion seem to influence perceptual responses, which are thought to be based on the body image.

The second hypothesis is that in both the mirror illusion and the rubber hand illusion the reaching movement will not be more directed towards the illusory hand when the illusion is induced, than when the illusion is not induced. Both illusions do not seem to have an effect on motor responses, which are thought to be based on the body schema.

2. Methods

2.1 Participants

18 right-handed subjects (14 female and 4 male, mean age 21.78 years, S.D. 2.05) participated in this study. Right-handedness was assessed with the Dutch handedness questionnaire (Van Strien,

1992; mean score 9.67, S.D. 0.69). Subjects with an overall score of seven or more were included in the experiment. All subjects gave informed consent prior to the experiment, and received a small fee for their participation.

2.2 Apparatus and materials

In this experiment two different set-ups were used. In both set-ups a basic wooden framework (75× 50 × 25 cm) was placed on a table. A magnetic kinematic recording device (miniBIRD, Ascension Technology Corporation) was used to record the motor responses at 86 Hz. Two markers of the device were attached to the tip of the index finger of each hand of the participant. A dummy marker was attached to the index finger of the rubber hand.

2.2.1 Rubber hand illusion set-up

In this set-up a right rubber hand was used. A removable board was placed vertically in the wooden framework, 16 cm from the right border, creating two compartments (see Figure 1). In the left compartment two small blocks were placed at the bottom of the framework, at a distance of 36 cm from each other. One block to indicate the position of the index finger of the participant's left hand (i.e. the non-illusion side), and one block to indicate the position of the index finger of the right rubber hand. In the right compartment (which was hidden from vision) two similar blocks were placed to indicate the two possible positions of the index finger of the participant's right hand. These blocks were placed at 15 and 18 cm distance from the position of the rubber hand. The distance between both index fingers of the participant was 51 cm or 54 cm, respectively. The removable board blocked the participant's view of these blocks. Only the left hand and the rubber hand were within the participant's view. The removable board could also be placed horizontally on top of the framework, occluding the hands from the participant's vision. A dark blue cloth was attached to the framework and placed over the participant's arms and shoulders preventing any visual clues about the position of the hands from trunk and shoulders.

2.2.2 Mirror illusion set-up

For the mirror illusion set-up a mirror (41 x 61 cm) was placed vertically in the framework, at 44 cm distance from the right side of the framework, creating two compartments (see Figure 2). The mirror also indicated the place of the body midline of the participant. The reflective surface was facing the participant's left hand. In the left compartment a small block was placed on the bottom of the framework, at 18 cm distance from the

mirror, indicating the position of the index finger of the participant's left hand. In the right compartment two similar blocks were placed to indicate the two possible positions of the index finger of the participant's right hand, at 34 and 37 cm distance from the mirror. These blocks were out of the participant's view. The distance between both index fingers and the distance between the illusion hand and the left index finger is the same as in the rubber hand illusion set up, which is 51 cm or 54 cm and 36 cm, respectively. Only the left hand and the reflection of the left hand were within the participant's view. The mirror could be removed and the removable board could be placed horizontally on top of the framework, occluding the hands from vision for the participant.

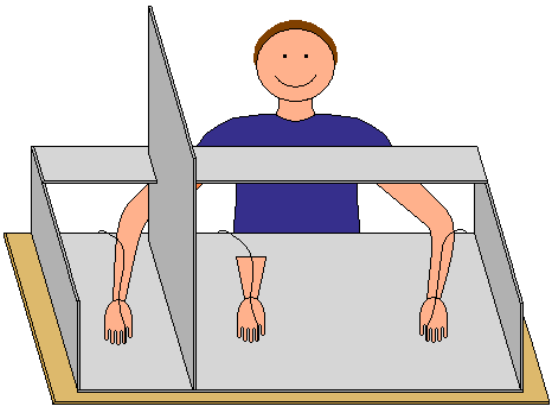

Figure 1. *The rubber hand illusion set-up.*

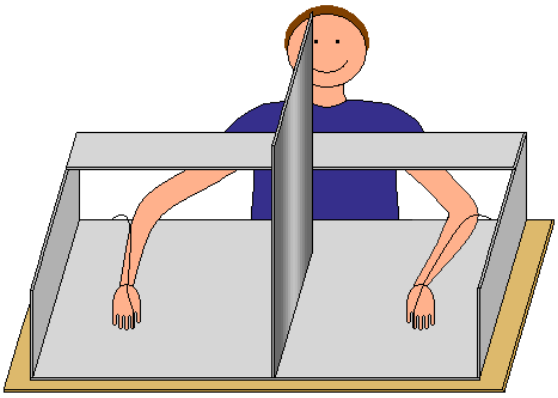

Figure 2. *The mirror illusion set-up.*

2.3 Design

We used a repeated measures design, with the factors Stimulation Type (synchronous, asynchronous), Illusion Type (rubber hand illusion, mirror illusion) and Response type (perceptual, motor). The experiment consisted of four blocks, with each block consisting of four trials. Two blocks of four trials were run with the rubber hand (two of which were run with asynchronous stimulation and two were run with synchronous stimulation) and two blocks of four trials were run with the mirror (two with asynchronous and two with synchronous stimulation). Synchronisation was randomised within each block, except for the last trial of each block, which was fixed to once synchronous and once asynchronous. This was done to make sure one rubber hand block and one mirror block ended with a synchronous and asynchronous stimulation trial. The participant was asked to keep the last trial of each block in mind. After each block the subjects were asked to fill in a questionnaire, respectively the Rubber Hand Illusion Questionnaire (based on Botvinick & Cohen (1998) and Ehrsson,

Holmes & Passingham (2005)) or the same questionnaire adapted to the mirror illusion. So a questionnaire was given after each type of trial (rubber hand synchronous, rubber hand asynchronous, mirror synchronous, mirror asynchronous). The blocks were presented in an ABBA or BAAB order to the participants, which was counterbalanced.

2.4 General procedure

The participants were asked to remove all jewellery and nail polish from their hands and to cut their nails short prior to the experiment. This was done to make sure their hands resembled the rubber hand as closely as possible. Each participant was seated behind a desk, on which the wooden framework was placed. The participants placed both their hands palms down on the bottom of the framework. The right index finger was placed on one of the two starting positions, out of the participant's view. This position was randomised between the trials and unknown to the participant. The left index finger was placed on the outer left block, within the participant's sight. The index finger of the illusory hand was positioned at the block in the middle, which was also visible to the participant. The participant was positioned in such a way that the midline of the body was centred between the left hand and the illusory hand. The illusion was induced by stroking the participant's index finger of the right hand and the index finger of the illusory hand synchronously or asynchronously, with two brushes for 90 seconds. The participant was instructed to watch the illusory hand continuously during the stimulation period. Hereafter, the participant was asked to close his eyes. A wooden board was placed on top of the framework, occluding the hands from vision. The participant was then asked to open his eyes. First, the participant was asked to provide a perceptual estimate of the position of the index fingers. For this response, the experimenter sat down in front of the participant and placed both index fingers on the edge of the wooden board. The experimenter moved the index fingers along the board, either beginning from the midline to the edges or vice versa. This starting position was counterbalanced. The participant was asked to indicate verbally when the position of the experimenter's index fingers matched the position of their own index fingers. The difference between both positions was assessed by the experimenter by using a ruler which was not visible to the participant. Subsequently, the participant was asked to perform a reaching movement with the stimulated right index finger towards the left index finger. A small board was held above the left hand of the participant during this reaching

movement, on which the participant landed with the right index finger, preventing tactile feedback between the two index fingers. This reaching movement was recorded by the magnetic kinematic recording device.

2.4.1 Rubber hand illusion procedure

At the start of the rubber hand illusion trials, the wooden board was placed vertically in the framework, occluding the right hand from the participant's vision. The index finger of the rubber hand was placed at the block in the middle, visible to the participant. The illusion was induced by stroking the participant's index finger of the right hand and the index finger of the rubber hand. After inducing the illusion the wooden board was removed and placed on top of the construction.

2.4.2 Mirror illusion procedure

At the start of the mirror illusion a mirror was placed in the framework, occluding the right hand from the participant's vision. The mirror was placed in this way that the reflection of the index finger of the left hand was positioned at the same place as the middle block. The illusion was induced by stimulating the participant's right and left index finger. After inducing the illusion the mirror was removed and the wooden board was placed on top of the construction.

3. Results

3.1 Perceptual response right hand

A 2×2 Repeated-Measures ANOVA with factors Illusion Type (rubber hand illusion versus mirror hand illusion), and Stimulation Type (synchronous (illusion) versus asynchronous (control)) was conducted. The difference between actual and perceived hand location of the right hand (perceptual error) was taken as the dependent variable. There was a significant main effect for Illusion Type ($F(1,17) = 14.552$, $p<0.001$), with the largest perceptual error for the mirror illusion compared to the rubber hand illusion. There was a significant main effect for Stimulation Type ($F(1,17) = 42.733$, $p<0.000$), with the largest perceptual error for the synchronous condition compared to the asynchronous condition. The two-way interaction between Illusion Type and Stimulation Type was also significant ($F(1,17) = 5.223$, $p<0.035$).

Paired samples T-tests were conducted to investigate the effect of Stimulation Type for both Illusion Types. This effect of Stimulation Type was significant for the rubber hand illusion ($t(17) = 4.531$, $p<0.000$), with the largest error towards the illusory hand after synchronous stimulation compared to asynchronous stimulation (see table 1 for means and standard deviations). This effect of Stimulation Type was also

significant for the mirror illusion ($t(17) = 6.768$, $p<0.000$), with the largest error towards the illusion hand after synchronous stimulation compared to asynchronous stimulation. Paired samples T-tests were conducted to investigate the effect of Illusion Type for both Stimulation Types. The effect of Illusion Type was significant for synchronous stimulation ($t(17) = -4.367$, $p<0.000$), with the largest error towards the illusion hand in the mirror illusion compared to the rubber hand illusion (see table 1). The effect of Illusion Type was also significant for asynchronous stimulation ($t(17) = -2.305$, $p<0.034$), with the largest error toward the illusion hand in the mirror illusion compared to the rubber hand illusion.

Table 1. *Means and standard deviations for illusion types and stimulation types combined (in cm) for the perceptual response with the right hand.*

	RHI synchronous	**RHI Asynchronous**	**MI synchronous**	**MI asynchronous**
Mean	9.201	6.992	11.493	8.160
SD	1.110	1.170	1.192	1.192

3.2 Perceptual response left hand

Another 2×2 Repeated-Measures ANOVA with factors Illusion Type (rubber hand illusion versus mirror hand illusion), and Stimulation Type (synchronous (illusion) versus asynchronous (control)) was conducted, with the difference between actual and perceived hand location of the left non-stimulated hand as the dependent variable. There was a significant main effect for Illusion Type ($F(1,17) = 11.659$, $p<0.003$), with the largest perceptual error for the rubber hand illusion (mean 0.683 cm; S.D. 0.588) compared to the mirror illusion (-0.212; 0.652). No significant main effect of Stimulation Type ($F(1,17) = 1.486$, $p<0.239$) and no interaction effect between Illusion Type and Stimulation Type ($F(1,17) = 0.120$, $p<0.733$) were found for the left hand. Figure 3 depicts an overview of the perceptual responses.

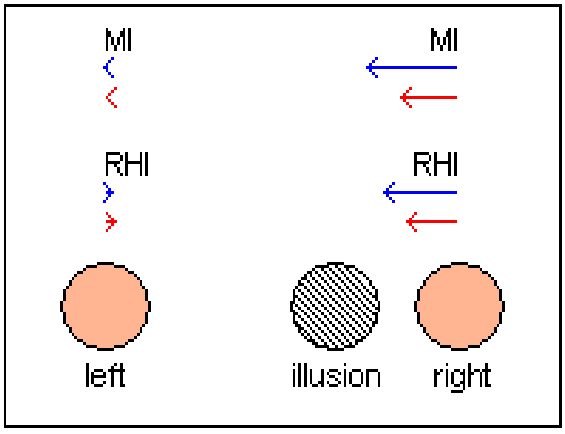

Figure 3. *The perceptual responses for the illusions for synchronous (blue arrows) and asynchronous (red arrows) stimulation for the left and the right hand.*

3.3 Reaching movement

A 2×2 Repeated-Measures ANOVA with factors Illusion Type (rubber hand illusion versus mirror hand illusion), and Stimulation Type (synchronous (illusion)

versus asynchronous (control)) was conducted for the reaching response with the right hand towards the left hand. The difference between perceived left hand location for each Illusion Type individually, and reaching endpoint error in the horizontal direction of the right hand was taken as the dependent variable. There was no significant effect of Illusion Type ($F(1,17) = 0.013$, $p = 0.911$), no significant effect of Stimulation Type ($F(1,17) = 1.264$, $p = 0.277$) and no interaction effect between Illusion Type and Stimulation Type ($F(1,17) = 0.018$, $p = 0.894$) (see table 2 for the means and the standard deviations).

Table 2. *Means and standard deviations for illusion types and stimulation types combined (in cm) for the difference between perceived left hand location and reaching endpoint error of the right hand.*

	RHI synchronous	**RHI Asynchronous**	**MI synchronous**	**MI asynchronous**
Mean	1.727	1.432	1.713	1.360
SD	0.737	0.697	0.648	0.742

4. Discussion

A common distinction between body representations is between the body image (perceptual responses) and the body schema (motor responses). In this study the difference between these two representations was investigated by comparing two bodily illusions, the rubber hand illusion and the mirror illusion. Both illusions were induced passively, by stroking the subjects' hands with brushes, which has not been investigated yet in the mirror illusion. In both illusions perceptual and reaching responses were compared.

We hypothesized that both illusions would have the same effect on the perceived position of the stimulated right hand after inducing the illusion. The results of the perceptual response of the right stimulated hand showed a significant difference between the two stimulation types for both illusions in the right hand. If the illusion was induced with synchronous stimulation, the right hand was perceived more towards the illusory hand in both illusions, than when asynchronous stimulation was applied. This suggests that the body image is influenced by inducing the rubber hand illusion and the mirror illusion. These results are consistent with previous research about the rubber hand illusion (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005, Kammers, Verhagen, De Vignemont & Dijkerman, submitted) and the mirror illusion (Holmes, Crozier & Spence, 2004; Holmes & Spence, 2005;

Holmes, Snijders & Spence, 2006).

A structural bias was found for illusion type in the right hand, which was independent of stimulation type. In the mirror illusion the right hand is perceived more towards the left than in the rubber hand illusion, whether the illusion was induced or not. The perceptual responses for the left hand showed a structural bias for illusion type as well, independent of the stimulation type. The left hand was perceived more towards the left in the mirror illusion than in the rubber hand illusion, whether the illusion was induced or not. A possible explanation for this structural bias to the left for the mirror illusion is the posture of the participant during the experiment with the mirror illusion. Because the participant had to watch the illusory hand in the mirror, the posture was more towards the left in the mirror illusion than in the rubber hand illusion. This could have caused the bias towards the left in the mirror illusion responses. Another explanation is the stimulation of the left index finger in the mirror illusion. This provides more tactile information about the location of the left index finger than in the rubber hand illusion. However, the difference between the mirror illusion and the rubber hand illusion in synchronous stimulation can not completely be explained by posture and/or stimulation of the left hand, because this difference is larger than the difference between the illusion types in asynchronous stimulation. The mirror illusion seems to produce a stronger relocation than the rubber hand illusion. One might argue that the sense of ownership (De Vignemont, 2007) plays a role in this difference. In the mirror illusion, the participant sees his own hand as the illusory hand. There is no doubt about the ownership of this hand, because of the visual similarity. In the rubber hand illusion the participant sees a rubber hand. The sense of ownership of this rubber hand is likely to be less profound than in the mirror illusion. This could be the cause of the weaker illusion in the rubber hand condition. Both illusions seem to influence the body image (as defined by the knowledge about the position of body parts with regard to each other (Paillard, 1999)), which is consistent with previous research (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005; Holmes, Crozier & Spence, 2004). But the mirror illusion has a stronger effect than the rubber hand illusion on the perceptual responses.

Our second hypothesis was that there would be no difference between both illusions in the reaching movement. Previous research suggests that the mirror illusion (with active stimulation) has an effect on reaching movements (Holmes, Crozier & Spence, 2004; Holmes &

Spence, 2005; Holmes, Snijders & Spence, 2006), and the rubber hand illusion (with passive stimulation) does not (Kammers, Verhagen, De Vignemont & Dijkerman, submitted). The results of our study showed no differences between both illusion types for the reaching responses and no effect of the illusion on the reaching responses when passive stimulation is used. This suggests that both illusions do not seem to have an effect on the body schema, which represents a map of the body based on the information necessary to make movements with the body (Gallagher & Cole, 1995).

Previous studies suggest that the estimate of hand position relies more on vision than on proprioception (Van Beers, Wolpert & Haggard, 2002). This suggests that for the perceptual response, vision is the dominant type of information. When making the reaching movement, however, new proprioceptive information comes available and this is the dominant type of information for the body schema (Paillard, 1999; Gallagher & Cole, 1995). The proprioceptive information reduces the importance of remembered visual information about hand position, and this could cause the reduction in both illusions. Previous studies suggested that this abolishment of the illusion would be only the case in the rubber hand illusion. Kammers, De Vignemont, Verhagen & Dijkerman (submitted) did not find an effect of the rubber hand illusion on reaching movements. In contrast, Holmes, Crozier and Spence (2004) did find an effect of the mirror illusion for the reaching response. In their study active stimulation was used. However, in our study only passive stimulation was used in both illusions, which does not provide proprioceptive information during the stimulation period. The proprioceptive information only becomes available during the movement in both illusions which causes the abolishment of the illusions. The perceptual response is mainly influenced by vision, the reaching response by proprioception. This distinction can be seen in deafferented patients (Gallagher & Cole, 1995). In these patients the body schema is considered to be distorted. These patients can only use vision, and not proprioception, for action. They can not move if they do not observe what they are doing.

More research in healthy participants is needed to investigate the effect of both illusions on perceptual and motor responses. It is not clear whether the differences in the perceptual responses between the mirror illusion and the rubber hand illusion were caused by the difference in body midline or by the stimulation of the left hand in the mirror illusion. The difference in body midline and stimulation

of the left hand in the mirror illusion could be avoided by using a video screen.

In conclusion the present results show a clear distinction of the effect of the illusions on the perceptual and motor responses which is in line with the body image and the body schema dissociation. The perceptual responses seem to depend on the body image and are affected by both illusions, while the reaching movements seem to depend on the body schema and are resistant to the illusions. This suggests that the passive induction of both illusions mainly affects the body image, and not the body schema.

References

Anema, H. A., Van Zandvoort, M.J., De Haan, E. H. F., Kappelle, L. J., De Kort, P. L. M., Jansen, B. P. W., & Dijkerman, H. C. (2007). Impaired body schema and body image: a double dissociation. Poster presented at The Second Cargèse School on Consciousness, Corsica.

Armel, K. C., & Ramachandran, V. S. (2003). Projecting sensations to external objects: evidence from skin conductance response. *Proceedings: Biological Sciences, 270*, 1499-1506.

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature, 391,* 756.

Buxbaum, L. J., & Coslett, H. B. (2001). Specialised structural descriptions for human body parts: Evidence from autotopagnosia. *Cognitive Neuropsychology, 18*(4), 289-306.

Costantini, M., & Haggard, P. (2007). The rubber hand illusion: Sensitivity and reference frame for body ownership. *Consciousness and Cognition, 16,* 229-240.

De Vignemont, F. (2005). A review of Shaun Gallagher, How the body shapes the mind. *Psyche.*

De Vignemont, F. (2007). Habeas corpus: The sense of ownership of one's own body. *Mind & Language, 22*(4)*,* 427-449.

Ehrrson, H. H., Spence, C., & Passingham, R. E. (2004). That's my hand! Activity in premotor cortex reflects feeling of ownership of a limb. *Science, 305,* 975-877.

Ehrrson, H. H., Holmes, N. P., & Passingham, R. E. (2005). Touching a rubber hand: Feeling of body ownership is associated with activity in multisensory brain areas. *The Journal of Neuroscience, 25*(45), 10564-10573.

Ehrrson, H. H., Wiech, K., Weiskopf, N., Dolan, R. J., & Passingham, R. E. (2007). Threatening a rubber hand that you feel is yours elicits a cortical anxiety response. *Proceedings: Biological Sciences, 104*(23), 9828-9833.

Gallagher, S., & Cole, J. (1995). Body schema and body image in a deafferented subject. *Journal of Mind and Behaviour, 16*, 369-390.

Holmes, N. P., Crozier, G., & Spence, C. (2004). When mirrors lie: 'Visual capture' of arm position impairs reaching performance. *Cognitive, Affective, & Behavioral Neuroscience, 4*(2), 193-200.

Holmes, N. P., & Spence, C. (2005). Visual bias of unseen hand position with a mirror: spatial and temporal factors. *Experimental Brain research, 166*, 489-497.

Holmes, N. P., Snijders, H. J., & Spence, C. (2006). Reaching with alien limbs: Visual exposure to prosthetic hands in a mirror biases proprioception without accompanying illusions of ownership. *Perception & Psychophysics, 68*(4), 685-701.

Kammers, M. P. M., de Vignemont, F., Verhagen, L., & Dijkerman, H. C. (submitted). The rubber hand illusion in action.

Lloyd, D. M. (2006). Spatial limits on referred touch to an alien limb may reflect boundaries of visuo-tactile peripersonal space surrounding the hand. *Brain and Cognition, 64,* 104-109.

Paillard, J. (1991). Knowing where and knowing how to get there. In J. Paillard (Ed.), *Brain and space* (pp. 461-481), Chapter 24.

Paillard, J. (1999). Body schema and body image: A double dissociation in deafferented patients. In G. N. Gantchev, S. Mori, & J. Massion (Eds.), *Motor control today and tomorrow* (pp. 197-214).

Schwoebel, J., & Coslett, H. B. (2005). Evidence for multiple, distinct representations of the human body. *Journal of Cognitive Neuroscience, 17*(4), 543-553.

Sirigu, A., Grafman, J., Bressler, K., & Sunderland, T. (1991). Multiple representations contribute to body knowledge processing. Evidence from a case of autotopagnosia. *Brain, 114*(Pt. 1B), 629-642.

Sirigu, A., Cohen, L., Duhamel, J. R., Pillon, B., Dubois, B., & Agid, Y. (1995). A selective impairment of hand posture for object utilization in apraxia. *Cortex, 31*(1), 41-55.

Tsakiris, M., & Haggard, P. (2005). The rubber hand illusion revisited: visuotactile integration and self-attribution. *Journal of Experimental Psychology: Human Perception and Performance, 31*(1), 80-91.

Tsakiris, M., Prabhu, G., & Haggard, P. (2006). Having a body versus moving your body: How agency structures body-ownership. *Consciousness and Cognition, 15,* 423-432.

Van Beers, R. J., Wolpert, D. M., & Haggard, P. (2002). When feeling is more important than seeing in sensorimotor adaption. *Current Biology, 12*(10), 834-837.

Van Strien, J. W. (1992). Classificatie van links- en rechtshandige proefpersonen. *Nederlands Tijdschrift voor de Psychologie en haar Grensgebieden, 47,* 88-92.

SUPPLEMENTARY INFORMATION GUIDE

Comparing bodily illusions: the rubber hand illusion and the mirror illusion

M.C.A.Winterman

The supplementary information guide consists of four questionnaires, two figures and a score form.

1. Supplementary questionnaires

The visual rubber hand questionnaire in English.

The visual rubber hand questionnaire in Dutch.

The visual mirror questionnaire in English.

The visual mirror questionnaire in Dutch.

2. Supplementary figures

Figure 1 depicts the mean questionnaire ratings for the synchronous and asynchronous condition for the rubber hand illusion.

Figure 2 depicts the mean questionnaire ratings for the synchronous and asynchronous condition for the mirror illusion.

Figure 3 depicts a score form for one participant.

Visual Rubber Hand Questionnaire

Name participant:
Date:

Part 1

Describe in a few words what you experienced during the experiment:

……
……
……
……

In Part 2 there are statements which you can affirm or deny on a 10 point scale. Whereby, 1 indicates "I strongly disagree" and 10 means "I strongly agree".

Part 2

1= I strongly disagree up till 10= I strongly agree

Please, keep in mind the last trial while filling the questionnaire

During the experiment there were times when:

		Score
1.It seemed as if I was feeling the touch at the location where I saw the rubber hand being touched	→	…
2. It seemed as though the touch I felt was caused by the stimulation on the rubber hand	→	…
3. It felt as if the rubber hand was my own hand	→	…
4. It felt as if my real right hand was drifting towards the left (towards the rubber hand)	→	…
5. It felt as if I had more than one right hand or arm	→	…
6. It seemed as if the touch I was feeling came from somewhere between my own hand and the rubber hand	→	…
7. It felt as if my real right hand was asleep	→	…
8. It appeared (visually) as if the rubber hand was drifting towards my own right hand	→	…
9. The rubber hand began to resemble my own real hand, in terms of shape, skin tone, freckles, etc	→	…
10. It felt as if the rubber hand and my own right hand lay closer to each other after the stimulation period as compared to the start	→	…

Finally,

11. It felt as if the distance between my both index fingers *

Became smaller Remained the same Became larger

(* draw a circle around the correct option)

How lifelike was this experience?

Rated on a scale from 1= "highly unrealistic" up till 10= "Highly realistic". → …

12. How lifelike and realistic was the experience that the rubber hand was your own?

Rated on a scale from 1= "highly unrealistic" up till 10= "Highly realistic". → …

Rubber Hand Experiment

Naam Proefpersoon:
Datum:

Vragenlijst Rubber Hand Visueel

Gebaseerd op Botvinick & Cohen (1998) en Ehrsson, Holmes & Passingham (2005)

Deel 1

Beschrijf in een paar zinnen wat u voelde, bemerkte of ervoer tijdens het aanraken:

……
……
……
……

Bij de vragen in deel 2 is het de bedoeling dat u aangeeft in welke mate u de gegeven bewering ook zo heeft ervaren op een schaal van 1 tot 10. Hierbij geeft een 1 aan "helemaal mee oneens" en een 10 "helemaal mee eens".

Deel 2

1= helemaal mee oneens t/m 10= helemaal mee eens

<u>Houd hierbij alstublieft de laatste trial in gedachten!</u>

Tijdens het experiment waren er momenten waarop:

		Score
1. Het leek alsof ik de aanraking voelde op de plek waar ik de rubberhand zag	→	…
2. Het leek alsof de aanraking die ik voelde veroorzaakt werd door de streling op de rubberhand	→	…
3. Het voelde alsof de rubberhand mijn eigen hand was	→	…
4. Het voelde alsof mijn eigen rechterhand verschoof naar links (in de richting van de rubberhand)	→	…
5. Het leek alsof ik meerdere rechterhanden of armen had	→	…
6. Het leek alsof de aanraking die ik voelde kwam van een plek ergens tussen de rubberhand en mijn eigen hand in	→	…
7. Het leek alsof mijn eigen rechterhand verdoofd voelde	→	…
8. Het leek alsof ik de rubberhand richting mijn eigen rechterhand zag (dus visueel) verschuiven	→	…
9. Het leek alsof de rubberhand eruit begon te zien als mijn eigen hand in termen van vorm, huidskleur, (moeder)vlekjes, etc.	→	…
10. Het voelde alsof de rubber hand en mijn eigen rechter hand dichter bij elkaar lagen na de stimulatie periode vergeleken met daarvoor	→	…

Tot slot,

11. Het voelde alsof de afstand tussen mijn beide wijsvingers
    kleiner werd gelijk bleef groter werd

Hoe sterk was deze ervaring?
Op een schaal van 1="zeer onrealistisch" tot 10= "zeer realistisch". → …

12. Hoe levendig en realistisch was het gevoel dat de rubberhand uw eigen hand was?
    Op een schaal van 1="zeer onrealistisch" tot 10= "zeer realistisch". → …

Visual Mirror Questionnaire

Name participant:
Date:

Part 1

Describe in a few words what you experienced during the experiment:

……
……
……
……

In Part 2 there are statements which you can affirm or deny on a 10 point scale. Whereby, 1 indicates "I strongly disagree" and 10 means "I strongly agree".

Part 2

1= I strongly disagree up till 10= I strongly agree

Please, keep in mind the last trial while filling the questionnaire

During the experiment there were times when:

		Score
1.It seemed as if I was feeling the touch at the location where I saw the mirror hand being touched	→	…
2. It seemed as though the touch I felt was caused by the stimulation on the mirror hand	→	…
3. It felt as if the mirror hand was my own hand	→	…
4. It felt as if my real right hand was drifting towards the left (towards the mirror hand)	→	…
5. It felt as if I had more than one right hand or arm	→	…
6. It seemed as if the touch I was feeling came from somewhere between my own hand and the mirror hand	→	…
7. It felt as if my real right hand was asleep	→	…
8. It appeared (visually) as if the mirror hand was drifting towards my own right hand	→	…
9. The mirror hand began to resemble my own real hand, in terms of shape, skin tone, freckles, etc	→	…
10. It felt as if the mirror hand and my own right hand lay closer to each other after the stimulation period as compared to the start	→	…

Finally,

11. It felt as if the distance between my both index fingers *

Became smaller Remained the same Became larger

(* draw a circle around the correct option)

How lifelike was this experience?

Rated on a scale from 1= "highly unrealistic" up till 10= "Highly realistic". → …

12. How lifelike and realistic was the experience that the mirror hand was your own?

Rated on a scale from 1= "highly unrealistic" up till 10= "Highly realistic". → …

Mirror Experiment

Naam Proefpersoon:
Datum:

Vragenlijst Mirror Visueel

Gebaseerd op Botvinick & Cohen (1998) en Ehrsson, Holmes & Passingham (2005)

Deel 1

Beschrijf in een paar zinnen wat u voelde, bemerkte of ervoer tijdens het aanraken:

……
……
……
……

Bij de vragen in deel 2 is het de bedoeling dat u aangeeft in welke mate u de gegeven bewering ook zo heeft ervaren op een schaal van 1 tot 10. Hierbij geeft een 1 aan "helemaal mee oneens" en een 10 "helemaal mee eens".

Deel 2

1= helemaal mee oneens t/m 10= helemaal mee eens

Houd hierbij alstublieft de laatste trial in gedachten!

Tijdens het experiment waren er momenten waarop:

		Score
1. Het leek alsof ik de aanraking voelde op de plek waar ik de spiegelhand zag	→	…
2. Het leek alsof de aanraking die ik voelde veroorzaakt werd door de streling op de spiegelhand	→	…
3. Het voelde alsof de spiegelhand mijn eigen hand was	→	…
4. Het voelde alsof mijn eigen rechterhand verschoof naar links (in de richting van de spiegelhand)	→	…
5. Het leek alsof ik meerdere rechterhanden of armen had	→	…
6. Het leek alsof de aanraking die ik voelde kwam van een plek ergens tussen de spiegelhand en mijn eigen hand in	→	…
7. Het leek alsof mijn eigen rechterhand verdoofd voelde	→	…
8. Het leek alsof ik de spiegelhand richting mijn eigen rechterhand zag (dus visueel) verschuiven	→	…
9. Het leek alsof de spiegelhand eruit begon te zien als mijn eigen hand in termen van vorm, huidskleur, (moeder)vlekjes, etc.	→	…
10. Het voelde alsof de spiegelhand en mijn eigen rechter hand dichter bij elkaar lagen na de stimulatie periode vergeleken met daarvoor	→	…

Tot slot,

11. Het voelde alsof de afstand tussen mijn beide wijsvingers
kleiner werd gelijk bleef groter werd

Hoe sterk was deze ervaring?
Op een schaal van 1="zeer onrealistisch" tot 10= "zeer realistisch". → …

12. Hoe levendig en realistisch was het gevoel dat de spiegelhand uw eigen hand was?
Op een schaal van 1="zeer onrealistisch" tot 10= "zeer realistisch". → …

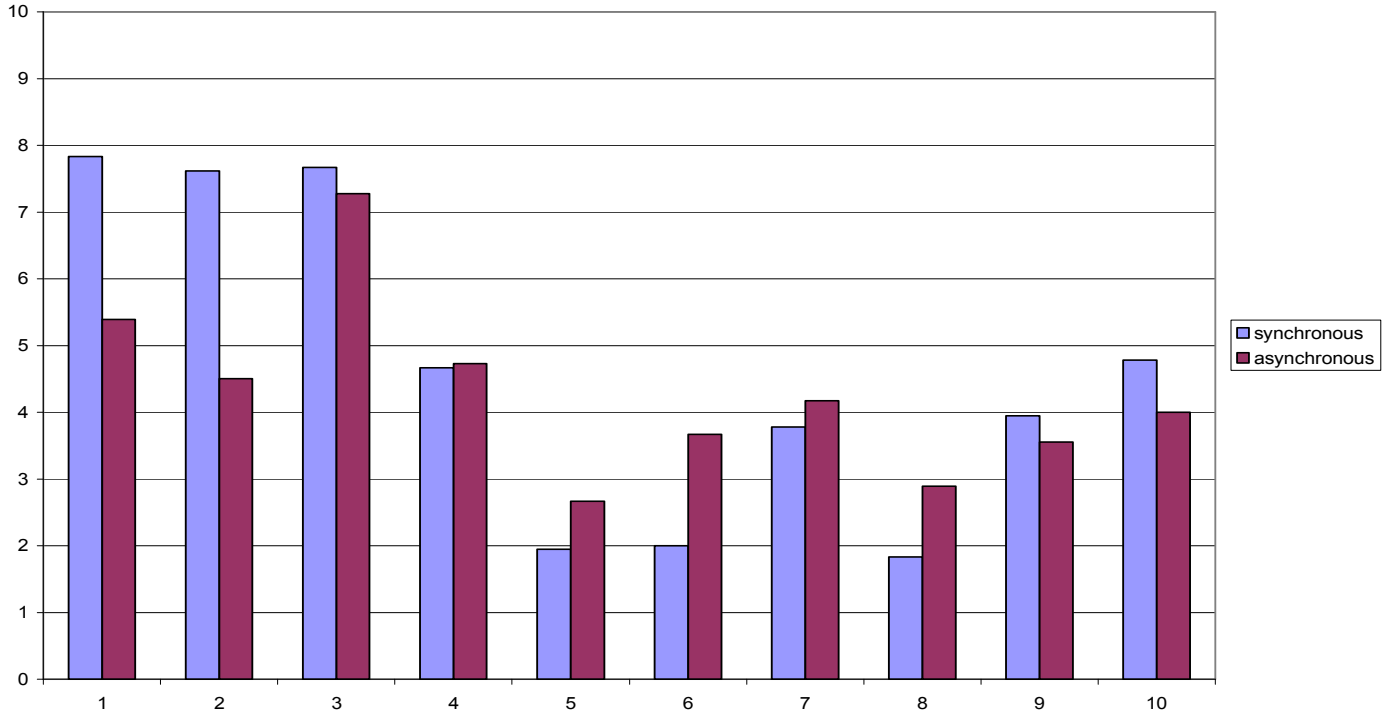

Figure 1. *Mean questionnaire ratings for the synchronous and asynchronous condition for the rubber hand illusion.*

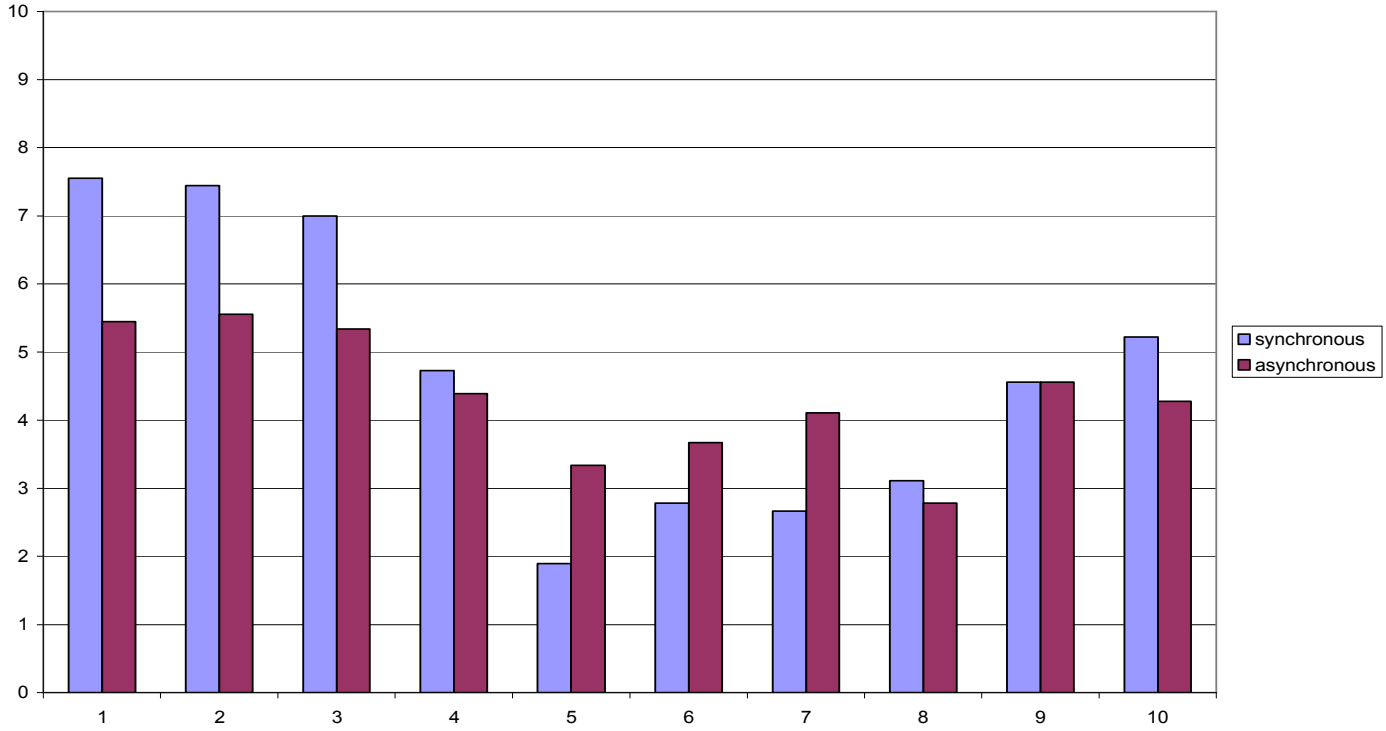

Figure 2. *Mean questionnaire ratings for the synchronous and asynchronous condition for the mirror illusion.*

All subjects received both the rubber hand and the mirror questionnaire two times. Once after synchronous stimulation and once after asynchronous stimulation. Figure 1 shows the mean

per stimulation type for the rubber hand illusion. Figure 2 shows the mean per stimulation type for the mirror illusion.

A 10×2×2 Repeated-Measures ANOVA with factors Question (1 to 10), Illusion Type (rubber hand illusion versus mirror hand illusion), and Stimulation Type (synchronous (illusion) versus asynchronous (control)) was conducted. There was a significant main effect for Question ($F(9,153) = 16.220$, $p<0.000$), subjects scored above 5 on questions 1, 2 and 3. There was no significant main effect for Illusion Type ($F(1,17) = 0.1169$, $p = 0.738$), and no significant main effect for Stimulation Type ($F(1,17) = 2.406$, $p = 0.139$).

The two-way interaction between Question and Stimulation Type was significant ($F(9,153) = 7.721$, $p<0.000$). No interaction effect was found for Question and Illusion Type ($F(9,153) = 1.298$, $p = 0.242$), and no interaction was found for Illusion Type and Stimulation Type ($F(1,17) = 0.035$, $p = 0.957$). The three-way interaction between Question, Illusion Type and Stimulation Type was not significant ($F(9,153) = 1.267$, $p = 0.259$).

These results show no effect of the stimulation type (inducing the illusion or not) on the sense of ownership.

Figure 3. *A score form for one participant.*

Proefpersoon																
sekse																
leeftijd																
datum																
rechtshandigheidscore																
		type	type	startpositie		Response		Response		trial		Vragenlijst scores				
		Illusie	Stimulatie	rechterhand		Perceptueel		Motor		type		Vraag	RHI-sync	RHI-async	MI-sync	MI-async
trailnummer						verschil score		TrialminiBIRD				1				
1		MI	a-sync	2						222		2				
2		MI	a-sync	1						221		3				
3		MI	sync	1						211		4				
4		MI	sync	2						212		5				
5		RHI	sync	2						112		6				
6		RHI	a-sync	2						122		7				
7		RHI	sync	1						111		8				
8		RHI	a-sync	1						121		9				
9		RHI	sync	1						111		10				
10		RHI	a-sync	2						122		11a				
11		RHI	a-sync	1						121		11b				
12		RHI	sync	2						112		12				
13		MI	a-sync	2						222						
14		MI	sync	2						212						
15		MI	sync	1						211						
16		MI	a-sync	1						221						