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Published in:
Book of Extended Abstracts, GW 2011: The 9th International Gesture Workshop, 25-27 May 2011, Athens, Greece

Publication date:
2011

Document Version
Accepted author manuscript, peer reviewed version

Mirror illusion using Augmented Reality: Investigating Multimodal Perceptual Distortions

Giselle Christoffersen*[1], Laura Petrini[1], Michael Nielsen[2], Carsten Dahl Mørch[1], Thomas Mygind[2], Thomas Moeslund[2], Lars Arendt-Nielsen[1]

[1] Center for Sensory Motor Interaction, Department of Health Science and Technology, Aalborg University, Denmark. [2]Department for Architecture, Design and Media Techonology, Aalborg Unversity, Denmark.
{Giselle Christoffersen; gcbc}@hst.aau.dk

Abstract. Mirror illusion has been widely and successfully used in therapeutic settings to treat chronic pain patients but the mechanisms involved in the mirror illusion are yet not well understood. The aims of this study are: (a) to investigate a relationship between body ownership and the visual illusion of an increased/decreased hand size; (b) to understand whether tactile acuity and inner representations of the hands can be modulated by a mirror illusion using an Augmented Reality setting. 33 healthy right- handed volunteers participated in the study. Results indicate, that the degree of ownership to the enlarged hand and to the hand in the control condition can modulate inner representation of the hands and tactile acuity. These findings could have an important impact on how to utilise augmented reality and mirror illusion in therapy.

Keywords: Mirror illusion, perceived limb size, body ownership, augmented reality.

1 Introduction

Mirror illusions (MI) as a therapeutic method has been widely and successfully used in several patient groups to relieve chronic pain and reduce visual hemineglect [1]. However, many individual differences in treatment outcome may imply that the mechanisms involved in MI are not be fully understood [6], and that there may be several limitations in the current methodological design of mirror therapy. The classical way to induce the illusion is by placing one limb behind a mirror that is situated along the observer's midline. When looking into the mirror, subjects have described the experience of "seeing through" the mirror's surface, as though it wasn't there [2], in which case the mirrored image is perceived as being attributed to one's own body. In normal circumstances, body ownership is based on a coherent formation of *body schema* and *body image*. This allows a unity of current sensory input with pre-existing cognitive or inner representations of the body [3]. However, chronic pain can cause distortions of the perceived size of a limb and reduce the ability to identify the location and characteristics of a tactile stimulus delivered to the painful site [4]. Thus it would be relevant to investigate among healthy subjects if tactile acuity can be

manipulated by *seeing* the limb in different sizes, and how these illusory sizes affect the sense of ownership to the mirrored limb. In the present study we investigate tactile acuity, inner representations of the hand and body ownership to the mirrored image in a group of healthy volunteers before, during, and after being presented to MI. The illusions were induced through an Augmented Reality (AR) system designed to act as a mirror. It was mediated through a Head Mounted Display (HMD) with a mounted camera facing the subject's own hands. Unlike Virtual Reality based systems [5], the visual augmentation was generated from the video feed of the subject's own hands instead of a virtual hand overlay controlled by tracking. The aims of this study are: (a) to investigate a relationship between body ownership and visual illusion of an increased/decreased hand size; (b) to understand whether tactile acuity and inner representations of the hand can be modulated by the visual illusion.

2 Methods

33 healthy right-handed volunteers were recruited (18 females, 15 males; age (mean±SD): 23.6±2.5 years). The experiment consisted of four conditions: (1) Control – No HMD and MI were included in this condition (2) Normal image - the left and right hands were the same size; (3) Enlarged image - The image of the left hand was enlarged with 1/3 of the size of the right hand; (4) Decreased image – The image of left hand was decreased with 1/3 of the size of the right hand. Conditions were randomized across all subjects.

Setup for the mirror illusions during the training session

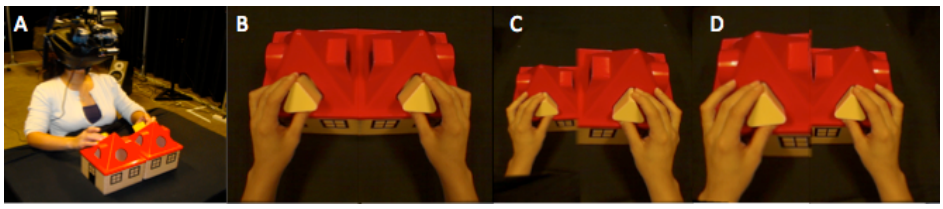

Fig1. Image A: The illusions were projected through the HMD on which the camera filming the hands was placed centrally. Image B depicts condition "normal" and C and D depict conditions small and large seen from the subject's perspective.

For each experimental condition, the procedure remained the same: *Illusion* – the projected image of the right hand was warped to create an illusory "mirror image" of the left hand. The size of the left hand was then manipulated (Fig 1, image C and D). *Training (5 minutes)* – Subjects put different shaped cubes into the corresponding holes synchronously with both hsands. *Tactile acuity* – two-point discrimination thresholds were attained by applying 8x2 tactile stimuli on the distal phalanx of the left index finger. The stimuli were applied from under the table through custom-made holes to conceal the stimulation area. For each stimulus, subjects evaluated whether they felt one or two points. The distance between the two points ranged between 1-7 mm. *Body ownership* – subjects were asked to fill in a questionnaire after each

condition. The variable "body ownership" consisted of 5 items. The first four began with the sentence " it felt like the left hand on the screen" followed by: (a) *was my hand*; (b) *was part of my body;* (c) *belonged to me;* (d) *was in my full control*. And finally: *(e) it looked like the left hand on the screen belonged to me*. Subjects evaluated from a scale from 1 to 6 whether they completely disagreed (1) or completely agreed (6) with each statement. *Inner representations of the hands* – while blindfolded, subjects freely drew an outline of the left hand starting from the base of the thumb and ending at the base of the little finger. This was done before and after *training* and *tactile acuity* tasks and three times for each trial on an A3 size paper by solely drawing with the right hand. The size of the hand drawing was calculated in cm^2.

3 Results

Significant results for ownership, tactile acuity and inner representations of the hand.

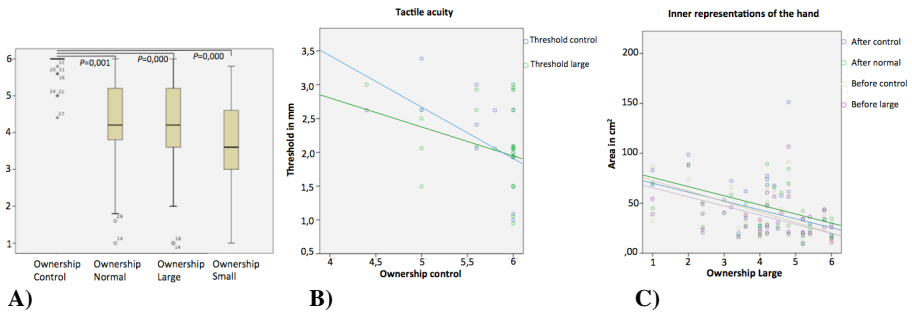

Fig2. Image A: shows significant differences for ownership among conditions. Image B and C: Regression lines show significant negative correlations between body ownership vs. tactile acuity and body ownership vs. inner representations of the hand

Friedman tests were performed on the following variables: *Ownership*, 2*-point discrimination thresholds*, and *hand drawings* vs. conditions. The test revealed that body ownership varied significantly for "control" vs. conditions "normal", "large" and "small" (p=0,000 – p=0,001)). Results for thresholds and hand drawings vs. conditions were not significant. Spearman correlations showed significant negative correlations between the degree of ownership towards the left hand in the control condition and the 2-point discrimination threshold in conditions: control and large respectively (r_s = -0.521, p = 0,002 and r_s = -0.348, p = 0,047). Significant negative correlations were also found between how much ownership subjects felt towards the left enlarged hand and the size of the hand drawings for conditions: before and after control (r_s = -0.383, p = 0,028 and r_s = -0.442, p = 0,01); after normal (r_s = -0.350, p = 0,046) and after large (r_s = -0.355, p = 0,043). N = 33 for all significant correlations.

3 Discussion

In the present study we sought to investigate the relationship between MI, body ownership, tactile acuity and inner representations of the hands and also if the classical design could be improved. The results show that among healthy subjects, *body ownership* to the mirrored image is significantly greater when subjects see their own hands without the illusion. Furthermore, seeing the left hand through the AR environment as small, large or normal does not have a significant impact on ownership. However, significant correlations show that the higher the sense of ownership to left hand in the control condition, the lower the threshold in conditions control and large. Additional significant correlations show that the stronger the sense of ownership to the enlarged left hand the smaller the drawings become for conditions *control* (before and after training and tactile acuity tasks), after normal and before large. Previous studies show that the loss of tactile acuity among people with chronic pain seems to correlate with the intensity of the pain, and when pain resolves, tactile acuity increases again [6]. Tactile acuity and inner representations of the body are therefore not fixed entities, but can be modulated. Ownership to the limbs (either perceived as normal, large or small sized) can be one of the important factors involved in this modulation and may perhaps also explain individual differences in mirror therapy.

4 Conclusion

The AR design applied in the current study can visually manipulate the size of a limb and induce a strong visual illusion that can modulate tactile acuity and inner representations of the hands. Manipulating the size of the limbs could have an impact on how to utilise MI and our AR design in therapy. Further studies should be conducted in order to investigate if there is a relationship between how cognition and personally traits have an impact on body ownership.

References

1. Oakley, D., Halligan, P.: Hypnotic mirrors and phantom pain: a single case study. *Contemporary Hypnosis, 19* (2002)
2. Ramachandran V. (1993) Filling in Gaps in Perception: Part II. Scotomas and Phantom Limbs. *Current Directions in Psychological Science, 2* (1995)
3. Tsakiris, M., Hesse, M. D., Boy, C., Haggard, P., & Fink, G. R.: Neural signatures of body ownership: a sensory network for bodily self-consciousness. *Cerebral Cortex* (2006)
4. Peters, M.L. & Schmidt, A.: A comparison of two-point discrimination threshold of tactual, non-painful stimuli between chronic low back pain patients and controls. *Pain, 44*. 57—60 (1991)
5. Murray, C.D., Pettifer, S., Howard, T., Patchick, EL., Caillette, F., Kulkarni, J., et al. The treatment of phantom limb pain using immersive virtual reality: Three case studies. Disability & Rehabilitation, Vol. 29, 18. 1465—1469 (2007)
6. Moseley, G.L., Gallace, A., Spence, C.: Is mirror therapy all it is cracked up to be? Current evidence and future directions. *Pain, 138*. 7–10 (2008)