

**Role of the multimodal integration and the mental imagery in the alleviation of pain and
eliciting of the rubberhand illusion**

Ph.D.Thesis

Gábor Hegedüs



Institute of Behavioral Sciences, Faculty of Medicine, University of Pécs

Leader of the Doctoral School: Prof. Dr. László Lénárd

Program Leader: Prof. Dr. János Kállai

Project Leaders: Prof. Dr. János Kállai és Dr. Tibor Szolcsányi

University of Pécs

Pécs, 2014.

I. Table of contents

I. Table of contents	1
II. Introduction	2
III. The Rubber Hand Illusion (RHI)	2
IV. Hypothesis	3
V. Demonstration of the fields of research	4
1. Effect of the reduction of visual and spatial attributions and mental imagery onto intensity of RHI	4
2. The rubber hand illusion increases heat pain threshold	5
VI. Summary	6
VII. Acknowledgement	7
VIII. Publications	7
1. Publications related to the thesis	7
2. Scientific papers	8

II. Introduction

Humans tend to defend themselves against pain, they strive to avoid or discard it instantly. We often use our imagination to reduce pain. With the attention we pay to our body parts, we may consider the body parts alien that are exposed to pain; the pain is present, but there is no extremity. However, there are cases, when we simply forget about our pain, due to the spontaneous distraction of our attention. Pain is much rather a psychological, than merely a physiological phenomenon, in which beyond the biological markers of the organism, the earlier experiences of the person are in connection with the pain, plus the present motivational status and the focus of the attention play equal roles. The perception of pain is in connection with how people relate to their own body and the attention towards the bodily sensations. Pain cannot be connected to a well-defined brain area, several areas take part in its sensation, evaluation and the execution of the behavioral answer in connection with pain. If an adequate method is available, imagination can easily activate the own curing power of the organism. Empirical data in connection with the role of imagination show that imaginary activity reduces the pain experience. Advantages of imagination can also be used in neurorehabilitation, not only in alleviating pain in connection with the different illnesses. Using imagination is successful in these areas, because of the functional equivalence that activates almost the same brain regions. Through the multisensory integration bodily and perceptual stimuli lead us to define our body, establishing a three dimensional body-schema about it. In the process of multisensory integration brain areas relevant to different modalities are not exclusively sensor-specific, but in many cases they are influenced by impulses arriving from other modalities. Multisensory integration expands to visual and tactile information occurring in body proximal space, the peripersonal space forming according to it. Body-schema is formed as the outcome of multisensory integration, which is forced to adapt according to the changed stimuli in many cases. For example, a missing tooth is still present in the representation of the body-schema for a long time, or in a more complex case, a missing limb may not wipe out from our memory until end of our life and may cause pain. This is because our perceptual experience forms automatic schema in the process of personality development. The elements derived from perceptual modalities associate to these schema, attributes of humans, living beings, objects appertain to this schema. However, in the absence of the attributes concerning the given object, the schema start to operate, and an automatic supplying a deficiency manifests, resulting in misperception of objects in swiftly changing conditions. The complex foreground-background situations can induce competition between the different schema (illusions) in different perceptual situations and lead to conclusions that are valid from one point of view, but are invalid from a different one. This phenomenon is observable in the cases of neuropsychology, psychopathology, altered states of mind, when depersonalization or derealization appears as a symptom. In some cases depersonalization can be so severe that patients have the illusion that their body or part of a body would be foreign and not belonging to them. Out-of-body experience also belongs to this group of phenomena. We term this kind of loss of identity or depersonalization „disownership“. Dissociations of peripersonal and extrapersonal space representation and the related body-schema disorders have a decisive role in the appearance of these kinds of neurological and psychopathological symptoms.

III. The Rubber Hand Illusion (RHI)

If our brain is unfit to integrate our perceptual experience into the body-schema, it tends to cut off the modality or body-part from our body-schema that causes illusions, by this enabling the emergence of dissociative states. The basis of illusions in connection with the body-schema, that our brain compares into the body-schema with all stimuli that constantly derive from

afferent fibres. If a contradiction occurs among these, the brain exerts to integrate and dissolve this. The method of RHI – which was developed to examine neurological disorders (mainly disorders with symptoms of depersonalization) – is based upon the proposition that people tend to experience an objects similar to a given body-part as their own body-part. With the help of RHI we can induce the visual, haptic and proprioceptive modalities that form the body-schema. Percieving the rubber hand as one's own hand causes changes in the homeostatic regulation of real hand. During the illusion significant physiological changes manifest in the depersonalized hand. If we install the rubber hand in a spatial position similar to one's own hand, and the rubber hand is touched synchronously with the real hand, the real hand becomes dissociated (loss of ownership) from the body-chema, and the rubber hand becomes integrated into the body-scheme, a certain ownership feeling occurs. This effect can be presented in 80% of people with different intensity in RHI experiences. Objective instruments (self-assessment questionnaires and analogous visual scales) are available to assess the intensity of the illusion, called proprioceptive drift. Thus, the paradigm of RHI is a suitable instrument for the assessment of the individual dissociative potential and for the analysis of behaviour in various reference frames of the body-scheme.

IV. Hypothesis

The aim of this thesis is to test through two research projects whether pain alleviation is possible by changing bodily awareness with the help of imagination in healthy volunteers' groups? As body-scheme derived from the multisensory integration, and sensory perception strongly correlate with imagination typical of the same modality, we assume that:

1. If we reduce the afferent information derived from the visual modality during multisensory perception, it will induce a measurable alteration in the body-scheme.
2. If we replace the missing information derived from the given modality with imaginary activity, it will compensate for the absence of real perceptual information typical of the visual modality, and thus the change resulting from stimuli reduction will not occur or it will manifest in smaller extent.

Imagination may modify bodily awareness. Several studies confirmed that physiological parameters were altered in the case of the concerned extremity. A question is arising, whether the physiological changes accessible with the paradigm of RHI are extensible onto pain perception?

3. If we create measurable changes in the body-scheme with the help of RHI, it will lead to the reduction of pain perception pertain to the concerned extremity.

V. Demonstration of the fields of research

1. Effect of the reduction of visual and spatial attributions and mental imagery onto the intensity of RHI

Background: The aim of this study was to test what happens if we gradually reduce the visual information derived from rubber hand, starting from the rubber hand setting to the invisible hand setting. (a) How visual information concerning the hand representation can contribute to the intensity of the illusion? (b) which factors of the illusion (ownership, disownership, mislocalization, proprioceptive drift) and in what rate are sensitive to the reduction of visual information? In order to measure these variables, we established an experimental setting in which beside the rubber hand setting there is an invisible hand setting, providing the lack of the complete visual stimulus. In addition, to examine imagination, we installed a further setting, that we called supported invisible hand illusion. This setting is a modified invisible hand condition, in which the presence of the hand contour serves to show the support of imaginary activity. The aim of this setting was to investigate, whether (c) the strength of the illusion is intensified by supporting the hand contour compared to the setting of the invisible hand?

Method: We installed a modified setting of RHI to answer the above questions. We applied three settings: rubber hand illusion (RI), visually supported invisible hand illusion (SII) and invisible hand illusion (II). To examine the reduction of the visual information and imagination concerning the intensity of the illusion, we tested the difference of the RI and II settings. We applied only synchronous stimulation in all three settings. The examination was implemented in the Institute of Behavioral Sciences, Medical School, University of Pécs.

Results: The results of the proprioceptive drift test showed that the illusion was most intensive in the RI condition, it differed significantly from II condition, while SII condition did not differ from the other two conditions. Based on the contracted questionnaire data, significant subjective experience of the illusion manifested, when the target of the illusion was the rubber hand, No significant difference could be seen between the SII and II conditions. There was significant difference between the subjective experiences of the participants in the three settings concerning the intensity of the illusion. The factor of mislocalization was sensitive only to the larger alteration of the visual information, but unappreciative to the smaller alteration of it, based on the questionnaire data. There was a significant difference between the RI and II conditions, and the SII and II. The experience of ownership emerged only at a diminished rate in the II condition, compared to the RI and SII conditions. There were significant differences among the three conditions in the embodiment dimension. The factor of disownership was not significant, so it was the most unappreciative to the alteration of visual information.

Conclusion: Visual information is not a necessary condition to the illusion, but it contributes to the intensity of the illusion. On the other hand, subjective factors of the illusion are sensitive to the alteration of the visual information in a different manner. The subjective factors of ownership and embodiment are the most sensitive. The subjective factor of mislocalization is less sensitive, the factor of disownership is unappreciative to it. Proprioceptive drift reacts only to considerable alteration of the visual information. Viewing the contour of the hand had a different role in evoking the illusion as viewing the rubber hand. These two conditions (RI and SII) are not comparable with each other in every respect, and it cannot be stated that the difference was only in rate of the visual information between them. A two dimensional hand contour differs from the three dimensional sight of the rubber hand qualitatively, therefore it is not likely that it matched the representation of the inner body-scheme by itself and caused alteration there. Furthermore, the brush stroking did not touch the drawn hand contour, therefore tactile stimuli did not associate with the visual stimulus derived from the drawn hand contour. The gap between these two things

must be filled by imagination. Our hypothesis proved true, visual information contributes to the intensity of the illusion, and with decreases of the visual information the intensity of it is reduced. We defined the way each component of the illusion depended on visual information, but we cannot unambiguously define how the difference between SII and II conditions depended on visual information and the process of imagination.

2. The rubber hand illusion increases heat pain threshold

Background: Accumulating evidence shows that manipulations of cortical body representation, for example, by simply viewing one's own body, can relieve pain in healthy subjects. Despite the widespread use of the rubber hand illusion (RHI) as an effective experimental tool for the manipulation of bodily awareness, previous studies examining the analgesic effect of the RHI have produced conflicting results. The aim of this study was to test whether RHI has any effect on pain threshold? Because viewing of the one's own hand purportedly has an analgesic effect, we assume that (a) during the synchronous stroking pain threshold will increase, and reach the level of pain threshold that is typical of the own hand setting, but will be higher than during the asynchronous stroking. (b) Besides the increase of the pain threshold in synchronous stroking, we will find increased objective (proprioceptive drift) and subjective (9 items questionnaire and visual analog scale) values, which clarifies that the illusion elicited and caused the increasing of the pain threshold.

Method: To test our hypothesis we used two settings (giving synchronous or asynchronous stimuli) and an own-hand setting (giving synchronous stimuli). We applied noxious heat stimuli to induce finger pain in 29 healthy subjects, and we recorded the participants' pain thresholds and subjective pain ratings during the RHI and during the control conditions. Two control conditions were included in our experiment – a standard one with reduced illusion strength (asynchronous stroking control) and an additional one, in which participants viewed their own hand. The examination was implemented in the Department of Neurology, Medical School, University of Pécs.

Results: Raw data showed that both the RHI and the vision of the own-hand resulted in slightly higher pain thresholds than the asynchronous stroking control (illusion: 47.79 °C; own-hand: 47.99 °C; asynchronous: 47.52 °C). After logarithmic transformation to achieve normality, paired t-tests revealed that both increases in pain threshold were significant (illusion/asynchronous: $p = 0.036$; own-hand/asynchronous: $p = 0.007$). In contrast, there was no significant difference in pain threshold between the illusion and the own-hand conditions ($p = 0.656$). Pain rating scores were not log-normal, and Wilcoxon signed-rank tests found no significant differences in pain ratings between the study conditions.

Conclusion: Our results seem to be the first in literature, attesting the pain reducing effect of the RHI. RHI increases heat pain threshold, and the analgesic effect of the RHI is comparable with that of seeing one's own hand. The latter finding may have clinical implications. The cause of difference between pain thresholds measured in synchronous and asynchronous conditions could be explained by the fact that the ownership/embodiment experience of the participants had emerged in different degrees, concerning the rubber hand. The homeostatic control of one's own hand had reduced, that is confirmed also by the physiological changes.

VI. Summary

The fundamental question of the examinations was aimed at testing whether it is possible to influence body awareness and the multisensory processes with the help of imagination, so that it can have an analgesic effect? The importance of this question is composed of two factors. In one respect, the question has clinical relevance, since a positive answer may open path for elaborating new methods of psychological pain alleviation. On the other hand, further examinations are necessary to find the answer that may lead us to new theoretical insights concerning the role of multisensory integration and imagination in the emergence of bodily awareness and the experience of pain. For testing, we chose HRI, as it is the most extensively studied and applied experimental paradigm in the research of the operation of bodily awareness. According to our approach, understanding the basic processes of RHI help us understand the dissociational processes of body-image and body-scheme, as well as the consequences of these processes. First we examined the effect of the reduction of the visual information and imagination. We concluded that visual information is not necessary for eliciting the illusion, but it significantly contributes to the strength of it. We supposed that the unity of the body-scheme does not disappear proportionally with the reduction of spatial and visual information. RHI can also be elicited if participants see only the intention of stroking of the rubber hand in its place, but actually they do not see the rubber hand. Participants tend to assume a relationship between the movement of stroking and the invisible rubber hand. Thus, people imagine that the the rubber hand is intended to be touched, even if the rubber hand is not visible. Secondly, we examined the effect of modification of bodily awareness on pain threshold with the paradigm of RHI. Based on our results, pain perception proved to be altered by the changes of bodily awareness. The processing of afferent multisensory signs and placing them onto the body (body image, body-scheme) and in the space (relation system of me and not me), constitutes the basis of the body-scheme. The multimodal stimuli-integration is in connection mostly with the temporoparietal junction. The sensory inputs from the body (motion of one's own body, visual, vestibular, auditory senses, etc.) are in connection with the stimuli derived from the environment. They also call for multisensory integration, moving the body parts, experiencing the acting agent, feeling of the self, the perspective of the ego-centric spatio-visual and the body-scheme. Consequently, RHI causes conflict on this level of processing among the different frames of reference, preventing the processing and correct localization of nociceptive stimuli in this way. Based on our findings, it can be stated that we can influence the process of multisensory integration with the help of RHI, disarrange the working of procession and modify bodily awareness by this means. We justified that RHI is elicited without the visual modality, but the strength of it will be weaker. We have unambiguously proved that the modification of bodily awereness has an effect on pain perceprion. We suppose that its reason is the considerable functional equivalence of the nervous system concerning the pain-matrix and the multisensory processing system.

VII. Acknowledgement

I would like to say thanks to Prof. Dr. János Kállai and Dr. Tibor Szolcsányi for providing assistance in selecting my research area and topic, in realizing the experiments and completing my thesis. They supported my work with their valuable advice and professional guidance. Further, I owe thanks to Prof. Dr. József Janszky for providing the objective conditions of the experiment, and to all of my colleagues, primarily Ádám Feldmann and Gergely Darnai. I also highly appreciated the work of Hajnalka Berecz. The thesis was written in the application number OTKA - K 106176 titled „Disaggregation of peripersonal and extrapersonal spatial representations: depersonalization, reality- irreality and virtual reality created by computer”.

V. Publications

1. Publications related to the thesis

Gábor Hegedüs, Tibor Szolcsányi (2012). The role of imagery in treatment and rehabilitation with special regard to pain management. *Mentálhigiéné és Pszichoszomatika* 13:(3) 311-335.

Gábor Hegedüs, Tibor Szolcsányi, Gergely Darnai, Krisztián Ivaskevics, Eszter Koltai, János Kállai (2012). The impact of the modification of body image on pain perception. *Review of Psychology* 19:(1) p. 96.

Gábor Hegedüs, Tibor Szolcsányi, Gergely Darnai, Krisztián Ivaskevics, Eszter Koltai, János Kállai (2012). The impact of the modification of body image on pain perception. In: Katalin Barabás, Erzsébet Kapocsi, Bettina Pikó, Csaba Hamvai, Melinda Látos, Margit Bóta, Melinda Vári-Kószó (Ed.) *XII. Days of Behavioral Sciences: extract volume*.

Gábor Hegedüs, Tibor Szolcsányi, Gergely Darnai, Krisztián Ivaskevics, Eszter Koltai, János Kállai (2012). The impact of the modification of body image on pain perception. In: András Vargha (Ed.) *Human face of the science: XXI. all-Hungarian scientific congress of the Hungarian Psychological Association: extract volume*. Hungarian Psychological Association, Budapest 2012. p. 313.

János Kállai, Tibor Szolcsányi, Gábor Hegedüs (2013). The Rubber Hand Illusion “It belongs to me, but it is not mine”. *Magyar Pszichológiai Szemle* 68:(3) 457-474.

Tibor Szolcsányi, Gábor Hegedüs, Gergely Darnai, Ádám Feldmann, Krisztián Ivaskevics, Eszter Koltai, József Janszky, János Kállai (2013). Impact of the rubber hand illusion on pain perception. In: András Vargha (Ed.) *World of our relationship: XXII. all-Hungarian scientific congress of the Hungarian Psychological Association: extract volume*. Hungarian Psychological Association, Budapest, 2013. p. 86-87.

Gábor Hegedüs, Tibor Szolcsányi, Ádám Feldmann, János Kállai (2014). Impact of the reduction of visual and spatial attributes on intensity of the rubber hand illusion. In: Vargha András (Ed.) *Unlimited Psychology: XXIII. all-Hungarian scientific congress of the Hungarian Psychological Association: extract volume*. Hungarian Psychological Association, Budapest 2014. p. 270.

Gábor Hegedüs, Gergely Darnai, Tibor Szolcsányi, Ádám Feldmann, József Janszky, János Kállai (2014). The rubber hand illusion increases heat-pain threshold. *European Journal of Pain* 18:(8), 1173-1181. (Impact factor: 3.218). DOI: 10.1002/j.1532-2149.2014.00466.x

2. Scientific papers

Tamás Bereczkei, Gábor Hegedüs, Gábor Hajnal (2009). Facialmetric similarities mediate mate choice: sexual imprinting on opposite-sex parents. *Proceedings of The Royal Society London B Biological Sciences* 276, 91-98. (Impact Factor: 4.857).

JánosKállai, Tibor Szolcsányi, GergelyDarnai, GáborHegedüs(2013). The rubber hand illusion: theory and method. In: András Vargha (Ed.) *World of our relationship: XXII. all-Hungarian scientific congress of the Hungarian Psychological Association: extract volume. Hungarian Psychological Association, Budapest* 2013. p. 86.

GergelyDarnai, TiborSzolcsányi, PéterKincses, GáborPerlaki, GáborHegedüs, JózsefJanszky, JánosKállai (2013). Active neural networks during induction of the rubber hand illusion: fMRI study. In: András Vargha (Ed.) *World of our relationship: XXII. all-Hungarian scientific congress of the Hungarian Psychological Association: extract volume. Hungarian Psychological Association, Budapest* 2013. p. 87.

JánosKállai, Tibor Szolcsányi, GergelyDarnai, GáborHegedüs, FeldmanÁdám, Krisztián Ivaskievics, Eszter Koltai. (2013). Role of personality factors in the induction of Rubber Hand Illusion. In: *Personality Psychology Foundation (PPF): The 1st World Conference on Personality*. Stellenbosch: p. 79.

GergelyDarnai, Tibor Szolcsányi, GáborHegedüs, PéterKincses, JánosKállai, JánosJanszky (2014). Conditioning of phantom hand and rubber hand:a further example of the bodily integrity and rubber hand illusion. In: András Vargha (Ed.) *Unlimited Psychology: XXIII. all-Hungarian scientific congress of the Hungarian Psychological Association: extract volume. Hungarian Psychological Association, Budapest* 2014. p. 270.

János Kállai, Gábor Hegedüs, Ádám Feldmann,Sándor Rózsa, Gergely Darnai, Tibor Szolcsányi(2014). Temperament characteristics and psychopathological syndromes related to the sensibility for the rubber hand illusion. In: AndrásVargha (Ed.) *Unlimited Psychology: XXIII. all-Hungarian scientific congress of the Hungarian Psychological Association: extract volume. Hungarian Psychological Association, Budapest* 2014. p. 270.

Kerekes Zsuzsanna, Hegedüs Gábor, Kállai János, Révész György, Tiszberger Mónika (2014). A szorongásra való érzékenység kérdőív faktoranalitikus vizsgálatának eredményei hazai mintán. In: Vargha András (szerk.) *Határtalan pszichológia – Unlimited Psychology: A Magyar Pszichológiai Társaság XXIII. Országos TudományosNagygyűlésének Kivonatköteté, 270 p.*

Gábor Hegedüs (2014). Types, theories, disorders and the development of personality (phylogeny, ontogeny).In:www.tankonyvtar.hu szerk.: Komoly Sámuel - TÁMOP-4.1.2.A/1-11/1-2011-0094 „Emberi életfolyamatok idegi szabályozása - a neurontól a viselkedésig. Interdiszciplináris tananyag az idegrendszer felépítése, működése és klinikuma témáiban orvostanhallgatók, egészség- és élettudományi képzésben résztvevők számára Magyarországon”, Dialóg Campus, chapter 6.a.