Table of Consents

1.0 Introduction

My interest in mirror visual feedback (MVF) was based on the acquaintance of this relative new treatment and its simple intervention which showed good results for alleviating pain syndromes, like phantom limb pain and complex regional pain syndrome, to which other treatments had showed little or no analgesic effects. In MVF it is tried to create an illusion where a person comes to perceive a mirror image as their own limb. This is done by placing a mirror vertically in front of the person's midline axis which makes it possible to watch the mirror reflection of the one side of the body while the other is hidden behind the mirror (Brodie, Whyte & Niven, 2007; Ramachandran & Altschuler, 2009).

This idea, to use visual feedback as treatment, originates from theories about the brain and it's functioning. Through investigations of the brains functioning, it has become apparent that the brain is capable of change - changes that sometimes are referred to as maladaptive reorganizations. MVF is used as an attempt to change back reorganizations of brain structures, which are thought to cause bodily perception disorders (Ramachandran & Altschuler, 2009). MVF seems to work, at least to some patients, but the exact mechanisms underlying the effects are not definitely clarified (Mercier & Sirigu, 2009).

What has become the pivot of the exploration and investigation in this thesis is that not all patients respond to the treatment with MVF, and the reasons for this remains unknown. Differences in patient characteristics e.g. degrees of reorganization in cortex, might account for some of the inter-subject variability, but studies suggest it cannot account for all the difference (ibid.; Dohle, Püllen, Nakaten, Küst, Rietz & Karbe, 2009). Another explanation for differences in patients proceed through MVF may be that the treatment is applied differently. There is only made a few attempts to write clinical protocols of how to use MVF, therefore practitioners' subjective experiences determine how MVF is applied (McCabe, 2010). This also makes it difficult to compare results from studies of MVF, because the intervention often differs, and because patients often engage in simultaneously treatments (Rothgangel, Braun, Beurskens, Seitz & Wade, 2010).

It has, as far as I know, not been investigated if differences in the clinical procedure during MVF can account for differences in patents proceeds. This seems relevant to do, in order to be able to improve MVF treatment, so more patients will benefit from it. Two studies; Mercier & Sirigu (2009) and Giraux & Sirigu (2003), has inspired to narrow down the investigation of clinical application practice of MVF to the tasks and movements used during MVF.

Mercier & Sirigu (2009) conducted a study to investigate why subjects respond differently to treatment with MVF. Inter-subject variability, like time since amputation, did not seem to account for differences in pain relief during MVF, but the patients, who responded well to the treatment, generally reported they needed to do an effort to move the phantom limb during MVF (Mercier & Sirigu, 2009). This observation was thought to be explained because of different levels of motor cortex activation during MVF, where those with the greatest activation might be the ones who respond to treatment with MVF. This was supported by findings from an fMRI study where there was seen a relationship between cerebral activation in primary motor cortex and a reduction in pain during MVF (Giraux & Sirigu, 2003).

Combined with the knowledge, that accomplishing complex tasks increases cerebral activation more than simple tasks do (Roland, 2003), inspired me on to investigate how MVFs effectiveness is influenced by different tasks, which elicit different degrees of cortical activation.

During the investigation of MVFs background another aspect of the treatment caught my interest. The treatment effect of MVF is build upon the notion that the perception of one's body can be manipulated and modulated. Most dominating is the Rubber Hand Paradigm (RHI), where it has been shown that during synchronized stimulation of a rubber hand and a person's real hand the person can come to perceive the rubber hand as belonging to their body, i.e. they come to perceive ownership of the limb (Botvinick & Cohen, 1998; Ehrsson, Spence & Passingham, 2004). This concept of ownership has been transferred to MVF, and is by many considered an important aspect of why MVF is efficient (Longo, Bette, Aglioti & Haggard, 2009; Mancini, Longo, Kammers & Haggard, 2010; McCabe, 2010). McCabe (2010) suggests the effectiveness of MVF is dependent upon the patient's ability to believe in the mirror illusion where the patient has to perceive the reflection in the mirror as being a part of their own body in order for MVF to work. These conclusions are most of all derived from studies of the rubber hand, and not been investigated systematical in MVF regime.

It can be quite problematic to draw conclusions from one type of study to another, and to resemble on practical experiences, which is why the second part of the study will investigate if feelings of ownership of the mirror reflection seem to influence the effectiveness of MVF.

The above presented considerations regarding MVF and the wish to investigate, why not everybody respond to MVF treatment and if the treatment can be improved, has resulted in the following problem definition.

1.1 Problem definition

Which influence does tasks of different complexity have on the effects of MVF and is perceived ownership necessary to achieve an effect from MVF?

1.2 Selection

The thesis aspires from clinical neuropsychological considerations of treatment and rehabilitation practices, and most discussions are based upon experimental findings. Therefore is has been chosen to investigate the problem definition experimentally. This makes it possible to investigate the causal relationship between tasks, ownership ratings and MVFs effect, and control for confounding variables. It should also secure the best comparison with other experimental findings of MVFs effect. It has also been chosen to use healthy participants primarily because of ethical concerns about testing the effects of tasks in MVF in patients. If the results seem promising to health, then it can be justified to try it as part of a treatment.

Selection of a topic and the request to write targeted about it, also requires deselecting areas to make sure the aim of the study stays as the central part of the thesis. Therefore I have chosen only to describe the necessary and general characteristics of the disorders treated with MVF. Also the theory section of the thesis is not thought to cover all the literature in the field, but is a selected review of studies and findings of interest to the current study.

1.3 Disposition

In the following the disposition of the thesis will be described, this will be followed by a brief introduction to the concepts used in the thesis.

The thesis is divided into six main sections: Background theory and evidences regarding MVFs treatment effects, exploration of tasks and ownerships potential influence on the treatment effect, the methods of the current study, presentation of the results and a discussion of the results and finally conclusion of the main findings.

1) A description of the background, development and some characteristics of the patients treated with MVF are provided in the beginning of the thesis, because it helps create an understanding of, how MVF works. After this the proposed mechanisms underlying MVFs effects are described, because they may play a fundamental part in explaining inter-subject variability of MVF treatment effect. During the background theory description,

limitations in the current knowledge of MVF and some potential negative effects of the treatment will be provided.

2) The second part of the theory will provide a discussion of the potential for tasks to influence MVF efficiency, and thereafter a discussion of how feelings of ownership might influence MVF. This will be followed by a short description of how feelings of agency might also influence MVF, and which confounding variable there will be controlled for. These discussions will end out in a construction of hypotheses, which will be investigated in the current study.
3) The methods section will provide a detailed description of the current experiment.
4) In the results the statistical analysis´ conducted on the data from the experiment will be presented. The results will be divided according to themes; all results concerning differences between mirror conditions, and control condition (without mirror) will be described first, including a description of the effects from an enlarging mirror, gender effects and baseline measurement effects. This is followed by results concerning the effects of tasks. At last ownership and agency feelings results is presented.
5) The final part will deal with a discussion of the results obtained in the current experiment. The discussion will be divided according to themes, like the results are, with effects of mirror conditions first, followed by tasks, ownership and at last agency effects.
6) At last the main findings and conclusions will be described, and suggestions to improvements of the experimental design will be presented.

1.4 Definitions

In the following the most central concepts and terms used in the thesis will be described.

1.4.1 Mirror visual feedback

Mirror visual feedback (MVF) is a method in which a mirror is used as a treatment device. Originally a mirror box was used, but a normal mirror is also suitable. In the classical procedure (see the cover) a mirror is placed vertical in front of the patient, with the mirror along the patient´s midline axis. Either arms or legs are placed on each side of the mirror, so the affected limb is hidden behind the mirror and the unaffected limb can be observed in the mirror. The patient is asked to watch and focus on the mirror reflection, and attempt to ignore the hidden limb. Usually this focus creates a visual illusion where the mirror reflection is perceived as the patient´s hidden limb. In the regular training, the patient has to make congruent movements with both the unaffected and the affected limb while observing the mirror reflection. If the limb is amputated, the patient should try to make imaginary movements with the missing limb (McCabe, 2010; Moseley, Gallace & Spence, 2008; Ramachandran & Altschuler, 2009).

The hidden hand, or *the non-mirror hand* will refer to the hand being placed behind the mirror, which is also the hand targeted in the treatment. Opposite will *the mirrored hand*, refer to the visible hand facing the reflective side of the mirror.

Mirror conditions or - *illusions* will refer to conditions, where the reflection of one hand is watched in either a neutral mirror or a concave mirror. The control condition, where the one hand is watched directly is referred to as *without* – or *no-mirror* condition.

1.4.2 Complex and simple tasks

Different areas in cortex are activated depending on the requirements of a task. Per E. Roland (1993) conducted a study to investigate different activation in the cortex during different tasks. He found that during simple tasks, such as taping a finger repeatedly or pushing a lever, blood flow increased in the primary somatosensory and primary motor cortex. When the tasks became more complex, like performing a sequence of movements, blood flow increased in premotor cortex as well. Last when subject performed movements which required more planning, as when finishing a maze, blood flow increased in prefrontal, temporal and parietal cortex (Kolb & Wishaw, 2009; Shumway-Cook & Woollacott, 2001).

I want to divide tasks into simple and complex according to the above described assumed difference in cortex activation.

Simple tasks will be defined as automate, repeated and easily performed tasks. This will include tasks, which are typically used in physiotherapeutic training of hands and wrists, e.g., moving the hands up and down, turning the hands or touching the thumb with the index finger.

Complex tasks will be defined as tasks which require planning and organization and which are goal-directed, which means, they have a specific accomplishment. This will include tasks like navigating through a maze, hit a ball, and fit a square cube into a square hole, a triangular block into a triangular hole or other object manipulations with specific purposes.

1.4.3 Body Image and Body Schema

> *"Repeated attempts to fractionate body awareness into different cognitive components have largely failed to arrive at universally accepted conceptions and definitions. In particular, the terms body schema and body image continue to be used by different*

> *authors in different manners, sometimes even with opposite meanings*" (Burlucchi & Aglioti, 2010, p. 26).

As the citing tells, much confusion and disagreements exists between understandings of bodily representation, especially between that of body schema and body image. The goal of this project is not to clear out the concepts and definitions of bodily representation, but I will shortly describe some attempts to clarify the differences and then describe the concept used in this project.

Body representation can be divided into different systems with specialized functions. The *What-system* is dedicated to recognition, the *where-system* are responsible for locating body parts and the *how-system* covers knowledge of how to do things (de Vignemont, 2010, p. 671). This differentiation in systems is also used in the definitions of bodily representations.

The *dyadic taxonomy* draws the distinction between body image and body schema. *Body schema* refers to a sensorimotor representation of the body, which controls action. Furthermore it is described as the dynamic representation of the relative positions of body parts derived from numerous motor and sensory inputs (e.g. proprioceptive, visual, tactile, and vestibular) which interacts in the execution of action (de Vignemont, 2010, p. 670; Schwoebel, Buxbaum & Coslett, 2004; Schwoebel & Coslett, 2005). This definition covers the notion of a how-system (de Vignemont, 2010, p. 671). The *body image* refers to all other representations of the body which does not guide action including conceptual, perceptual and emotional (de Vignemont, 2010, p. 670). Both the what- and the where- systems are a part of the body image.

The concept of body schema and body image are, despite the above definitions, often used uniformed. E.g. MVF is sometimes described as restoring the body image (Casale et al., 2009; Lotze & Moseley, 2007; Murray et al., 2007), and at other times as restoring the body schema (Moseley, 2004a). Sometimes body image is used in the context of motor control (Sirigu & Giraux, 2003), which is the ability to regulate and direct the mechanisms essential to movement

The confusing use of the concept, has lead me to use the term of *body image* throughout the *theory section* of the thesis. The term will be used as a uniform concept of both body schema and body image as defined above and independent on which term the authors use. In the *discussion* body schema and body image will be used, in accordance with the definitions formulated by de Vignemont.

1.4.4 Feelings of ownership

When referring to the term ownership, it will be a referral to the subjective feeling of body-ownership, i.e. the feeling one´s body belongs to oneself, in a way other objects does not. It is possible to acquire this feeling of ownership of objects, when the body image is manipulated as in MVF. Ownership will therefore be used to describe, how much the mirror image are perceived as being a part of one´s body.

1.4.5 Sense of Agency

Agency will be defined in the term used by Gallagher (2000) "*sense of agency: The sense that I am the one who is causing or generating an action. For example, the sense that I am the one who is causing something to move*" (p.15). In this way a sense of agency are only perceived during voluntary movements. When referring to agency feelings of the mirror reflection, it means, the feeling that I am the one controlling and generating the actions of the mirror reflection.

2.0 Mirror Visual Feedback: background, theory, use and further directions

2.1 The background for MVF

In 1992 Ramachandran and Altschuler introduced MVF for chronic pain of central origin and hemiparesis following stroke (cf. Ramachandran & Altschuler, 1999). The foundation for the development was experimental findings, which changed the understanding of the brain, and its functioning. For example the discovery of the brains plasticity and malleability through the rubber hand paradigm (see section 2.1.4). The final introduction and development of MVF followed from investigations of phantom limb pain (PLP); its origin and possible treatment. In the next section major experimental findings creating the ground from which to MVF developed will be outlined. This is done to create an understanding of the proposed mechanisms behind the effects of MVF.

2.1.1 New understanding of the brains functioning

A review of the history of neuropsychology reveals a continuous debate about the functional organisation of the brain. The two dominating, opposing views were between the *localization theory*, which states that the brain is divided into highly specialized modules, and the *holistic theory* where the brain are seen as a homogenous functioning organ (Gerlach, Starrfelt, Gade & Pedersen, 2011a; Kolb & Whishaw, 2009). Despite disagreement of the organisation, the general views on both sides were that the adult brain was relatively stable. When neural connections were laid down during foetal development and infancy, they were presumed to remain fixed throughout the rest of the life, without possibilities of forming new neural connections.

After the middle of the 20th century the dominating view of the brain became that of *connectionism*, where the brain was seen as malleable with strong interactions between specialized brain modules. This change in perspective had great implications for treatment practice, because a faith in possibilities of recovery after brain damages arose. At the root of this view were new experimental methods and research, which made findings possible that contradicted the old view of the brain (Ramachandran & Altschuler, 2009; Wall & Wolstencroft, 1997). It was found that significant reorganizations in the cortex of adult primates followed amputation, which supported the view that the brain is capable of changes not only in the early years, but also later in life (Merzenich et al., 1983a; 1983b; Pons et al., 1991). The mechanisms responsible for the reorganisation remains to be fully understood, but the consequences of reorganisations have been explored, which will be described in the following section.

2.1.2. Penfield's Homunculus and referred sensation

V.S. Ramachandran, D. Rogers-Ramachandran & M. Stewart (1992) examined the effects of reorganisation following arm amputation, and discovered that tactile stimulation applied to the face would be misallocated as being on the missing arm. This misallocation was named *referred sensations* (Ramachandran et al., 1992), and can be explained through Penfield´s homunculus introduced by W. Penfield and E. Boldrey (1937) figure 2.1. The Penfield's homunculus depicts the subdivision of primary motor cortex (M1) and primary somatosensory cortex (S1). In the homunculus of the primary motor cortex, it´s possible to see which areas are responsible for movement execution for specific body parts. Because the body is symmetrical, a reversed representation of this homunculus can be found in each hemisphere (ibid.). The original drawing of the homunculus is simplistic and many more homunculi exist, which Penfield also recognized (Kolb & Whishaw, 2009). In figure 2.1, the hand and arm representations are localized right next to the face representation. After amputation of a limb the representation of the limb still exists in the brain, but because of missing sensory information the adjacent regions "invades" the deafferented[1] region. When this happens, sensory stimulation of the face not only activates cells in the face representation area, but also activates the representation of the hand, which is felt like touch on the missing hand (Nikolajsen & Jensen, 2001; Ramachandran & Altschuler, 2009; Ramachandran & Hirstein, 1994; Ramachandran et al., 1992).

[1] Deafferentation are elimination or interruption of afferent sensory information

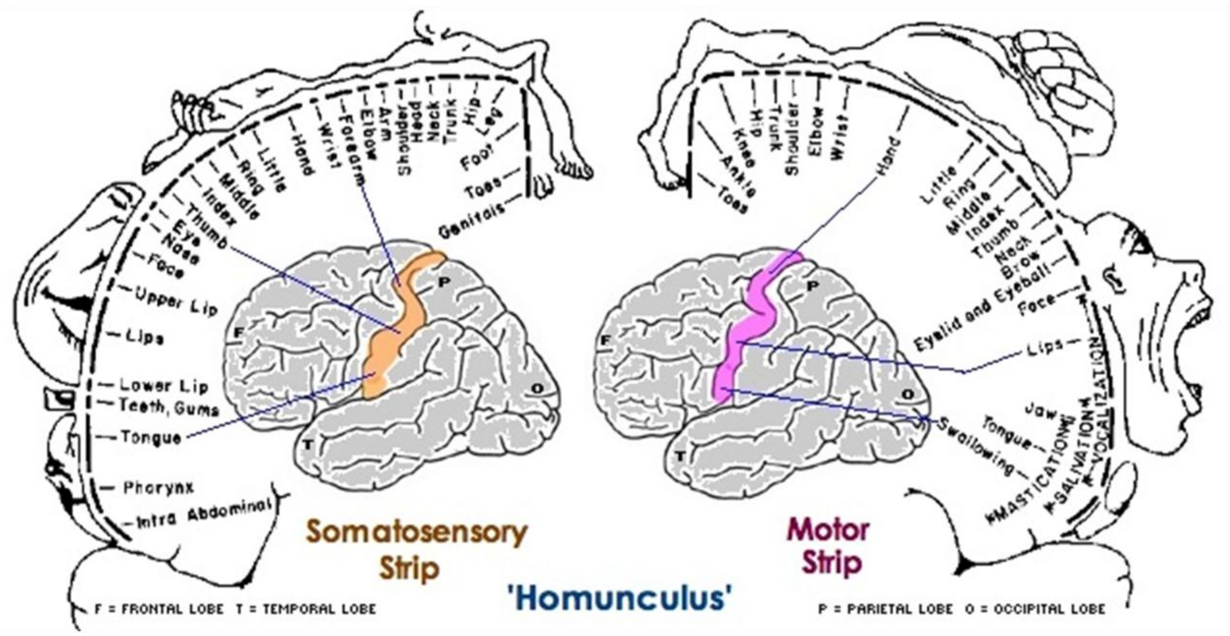

Figure 1*: Penfield´s Homunculus depicturing representations of the body in the brain* (Joseph, 2000).

The discovery and exploration of body representations and especially referred sensations illustrate the malleability of the human brain. It also contributed to the theoretical explanations for, why phantom limbs and phantom limb pain are experienced, which will be described in the next section. After this I will return to the functions of the body representation, and how easily body representations are changed, which is what MVF take advantage of.

2.1.3 Phantom limbs and phantom limb pain

In the following the experience and origin of phantom limbs will be described, since it is research in this field that led to a development of MVF as a treatment. Much attention has been given to the experience of phantom limbs, and especially to the experience of phantom limb pain (PLP), because of the difficulties in treating the often intolerable pain. Brodie et al. (2007) states more than 68 different treatments exist for PLP, but most of them are ranging from ineffective to only slightly effective(Ramachandran & Altschuler, 2009).

The term phantom limb was introduced around 1870, and was used to describe the vivid experience of an amputated body part being "present". 90-98% of all amputees experience phantom limbs (Flor, 2002; Nikolajsen & Jensen, 2001; Ramachandran & Hirstein, 1994), and among them 50-85 % suffer from severe unremitting pain in their phantom limb. The pain is experienced very differently, carrying characteristics such as burning, cramping, stabbing, or throbbing, and it can continue many years after amputation. PLP should be distinguished from non-painful phantom sensations such as itching and tingling and feelings of heat and cold in the phantom, all though this can be almost as intolerable as PLP (Brodie et al., 2007; Nikolajsen & Jensen, 2001). Several theories of phantom limbs and PLP have been proposed. In the following, theories for PLP will be described which relates to the proposed mechanisms behind MVFs effect.

As mentioned (section 2.1.2) phantom limb experiences may arise when the area representing the missing limb is invaded by sensory information from the adjacent areas. The degree of cortical reorganisations correlates with the degree of PLP, where greater reorganisation causes higher level of pain (Flor, 2002), but the relationship between pain and reorganization is not clear; cortical reorganization causes pain, but pain may enhance cortical reorganization (Lotze & Moseley, 2007). People with congenital limb loss do not show the same reorganisations in cortex as traumatic limb amputees and in addition, they are less likely to experience phantom limbs and PLP. This supports the view that reorganisations are a main contributor to PLP (Montoya et al., 1998). The pain might arise from errors caused by the reorganization, where some sort of cross wiring accidentally connects sensory channels to pain areas, resulting in touch sensations experienced like painful stimulation (Ramachandran & Altschuler, 2009). Remapping in itself is thought to be a pathological process, which may cause pain, but it cannot account for all aspects of phantom sensations e.g. why some people have voluntary control of the phantom limb and others do not (Ramachandran & Hirstein, 1994).

Pre-amputation conditions may explain differences in voluntary control of the phantom limb. People, who had their limb paralyzed before the amputation, often report missing ability to voluntarily control movement in the phantom - the brain may have stored a `*learned paralysis*´. Voluntary control is desirable because the phantom can be locked in an awkward and painful position, which is the case when arm-amputees experience their digits dig into the palm in *clenching spasm* (Ramachandran, Rogers-Ramachandran & Cobb, 1995). In the same way people without pre-amputation paralysation sometimes lose the ability to move a phantom limb. This may happen, because motor command send to the phantom limb is never accomplished, which leaves a learned paralysis (Ramachandran, 1994; Ramachandran & Hirstein, 1994). When motor commands are sent to the phantom limb the motor system expect to receive sensory feedback, which is used to evaluate the consequences of the movement. After amputation such information remains absent. This *mismatch* between motor commands sent to the missing limb and absent visual and proprioceptive information has also been claimed to cause pain sensations (Ramachandran & Altschuler, 2009).

The mismatch theory inspired Ramachandran and colleges (1995) to try to "resurrect" the phantom limb using a mirror. By mirroring the remaining limb, it was tried to create an illusion that the missing limb was moving. This was thought to restore congruence between motor commands sent to the phantom limb and visual and proprioceptive information returning. This in turn should either help change back cortical reorganisations followed by the amputation, help regain voluntarily control and/or unlearn a learned paralysis (I will return to the efficacy of MVF in section 2.2.1 and describe the mechanisms by which it seems to work in section 2.2.5).

2.1.4 Body representation manipulation

One of the reasons disturbances in sensory feedback processes are able to generate such great implications, is because the mental representations of the body is affected. The representations of our body serve important functions. Especially the representation in primary sensory cortex (S1) and primary motor cortex (M1) seems crucial in our functioning, because they give us a sense of being and a sense of ability to generate action (Berlucchi & Aglioti, 2010; de Vignemont, 2010; Gallese & Sinigaglia, 2010; Reed, Stone & McGoldrick, 2005; Schwoebel & Coslett, 2005). Some of the most prevalent functions of the body representations are adjustment of posture, guidance of movement, and integration of sensory and efferent information in order to adjust and correct motor errors. In other words representations of our bodies tell us, where our body is and how we should move in order to achieve our goals (Schwoebel, Buxbaum & Coslett, 2004; Schwoebel & Coslett, 2005).

The importance of the bodily representations becomes problematic, because the representations are quite easily changed. An example of the easy modulation is that a blindfolded subject easily can get the feeling that their nose is getting longer by simultaneously receiving a tap on their own nose while tapping a nose placed half a meter in front of them (Lotze & Moseley, 2007; Ramachandran & Hirstein, 1994).

This easy manipulation of the body image is also used in MVF. The reason it is possible to manipulate the body image in MVF depends on an unequal importance given to the senses. Back in 1964 Rock & Victor investigated the effects of contradictory information given through vision and touch, where people tended to rely on what they saw, and not what they felt. The different weighting of the information from the senses are thought to arise, because "*the brain assigns different weight to different sensory inputs depending on their statistical reliability*" (Ramachandran & Altschuler, 2009, p.1699).

Visions domination of tactile and proprioceptive information has also been used in *the rubber hand paradigm* (RHI), where subjects are fooled into thinking a rubber arm belongs to their body.

The experimental setting is simple: A subject is seated with the left arm resting hidden e.g. behind a screen or in a box. Besides the real hidden hand, the rubber hand is placed. If the rubber hand and the subject´s real hand are simultaneously stroked with a pencil by the experimenter, an illusion is created in which the strokes are perceived as being felt on the rubber hand (Botvinick & Cohen, 1998). The misattribution of sensations to the rubber hand can actually cause physiological changes in the real hand. For example if the rubber hand after being incorporated into the subject body image suddenly are punched, then there is seen increased sweating, caused by an autonomic arousal (Ramachandran & Altschuler, 2009).

The manipulation of body images is taken to the limit by Altschuler & Ramachandran (2007), who create an illusion that a person stands outside himself, just using two full frontal mirrors facing each other. When looking into one of the mirrors, the person can see his own back, which is perceived as another person (see Altschuler & Ramachandran, 2007, p. 633 for experimental setting). The same illusion can be created using a head-mounted display and a video camera placed behind the participants back (Ehrsson, Wiech, Weiskopf, Dolan & Passingham, 2007; Lenggenhager, Tadi, Metzinger & Blanke, 2007 - See Lenggenhager et al., 2007, p. 1097 for experimental setup).

2.1.5 Summary

The idea of using mirrors to treat various body perception disorders originated in an understanding, that the brain is capable of change. These changes might be maladaptive as is the case of phantom limb pain, where the degree of cortical reorganisation following amputation corresponds to the experienced pain. The same ability to create cortical changes are utilised in MVF. Another experimental finding which paved the way for a development of MVF was the acquired knowledge that body perception are easily manipulated, as when a person comes to perceive a rubber hand belonging to his own body. This illusion is able to occur because there are given unequal importance to our senses, with vision being the sense we rely on, if incongruent sensory information are received.

2.2 Current evidence

After laying out the ground from which MVF developed, the next section will focus on the current evidence of MVFs effectiveness, as well as elaborating which mechanisms by which MVF is thought to work.

2.2.1 Studies of MFV to amputees

The above described findings inspired Ramachandran and colleges (1995) to try to use a mirror to create an illusion, that an amputated limb became resurrected. Nine upper limb amputees were exposed to the mirror illusion. A mirror was placed vertically on a table in front of the patients so they could watch the reflection of their remaining arm, which gave the impression that the reflection superimposed the phantom. The results were promising, as seven patients felt that when the normal arm moved, the phantom moved as well. The effect occurred in one patient despite he had not been able to move his phantom in ten years. Four out of five patients could move the phantom during clenching spasms (see section 2.1.3) and relieve the pain immediately, despite the clenching spasms normally lasted for hours. The effects of the mirror could only be achieved with the eyes open (Ramachandran et.al., 1995). One patient used the mirror for 3 weeks; 15 minutes a day, which resulted in a permanent telescoping[2] only leaving the phantom fingers behind, and in addition a reduction in PLP was experienced. This was one of the first reports of the effectiveness of MVF in treatment of PLP.

MVF has also proved to benefit lower limb amputees, and the treatment seems to be superior to mental visualization of movements and control sessions where the mirror is covered (Chan et al., 2007).

MVF treatment has also expanded to virtual reality systems. The advantage of these systems is that the patient is allowed to move more freely than the mirror allows. An example of a virtual reality system is the one created by Murray et al. (2006), where the patient is presented in a virtual room in an embodied point of view. Sensors on the remaining limb are used to present and move the missing limb, so the patients have to move their anatomical opposite limb in order to move the phantom limb. The visual feedback seems to increase ability to move the phantom and in addition reduce pain (ibid.). Other studies have also used different virtual or augmented reality systems to create a virtual image of the missing hand or a paralyzed hand with promising results (Eng et al., 2007; Giraux & Sirigu, 2003; Mercier & Sirigu, 2009). The results might be promising but should be interpreted with caution since all studies have only included a small sample of patients.

[2] Telescoping is the experience that most of the phantom limb disappears, but one part stays present in consciousness. E.g. the phantom fingers can be experienced as dangling from the shoulder stump. This might happen because some body parts are overrepresented in cortex, e.g. the hand and the digits, which can be seen in Penfield's Homunculus figure 2.1 (Ramachandran & Hirstein, 1994).

2.2.2 Hemi paresis, complex regional pain syndrome and hand surgery

The promising results from studies of MVF applied as treatment for PLP have inspired to try the treatment out on other groups of patients suffering from e.g. stroke, CRPS, fibromyalgia and more recently cerebral palsy.

Stroke often causes hemiparesis or hemiplegia; paralysis of contra-lesional side of the body. MVF has tried to be included as a part of rehabilitation programs for stroke patients, because it has been suggested that part of the hemiplegia is caused by a learned paralysis as described for amputees with PLP (section 2.1.3). In line with the modern view of the brain as plastic and capable of some recovery after damages, paralysis following stroke is thought not exclusively to be caused by irreversible damage to the brain. Part of the paralysis may be caused by a swelling and edema of white matter around the injured brain area which disappear within a few days or weeks. The swelling interrupt corticofugal signals and leave behind a learned paralysis (Ramachandran, 1994; Ramachandran & Altschuler, 2009). False visual feedback received through a mirror illusion carry the potential of reversing the learned paralysis by giving the visual impression that the affected limb can move. As for treatment of PLP the patient are seated in front of a vertically placed mirror with a hand or leg on each side of the mirror. The mirror faces the unaffected hand and bilateral synchronized movements are carried out, as good as possible with the affected hand, while the mirror reflection of the unaffected hand is being watched. Current evidence seems to support that MVF improves recovery from hemiparesis following stroke, but a high variability between patient's proceeds suggests MVF is beneficial to some patients but not everybody (Altschuler et al., 1999; Michielsen et al., 2010; Ramachandran & Altschuler, 2009; Sütbeyaz, Yavuzer, Sezer & Koseglu, 2007; Yavuzer et al., 2008).

CRPS carries similarities with stroke and PLP, and due to limitations in previous treatments researchers tested MVFs possible analgesic effects on CRPS. CRPS is a condition characterised by intense and unexplainable pain, muscle weakness, and tremor a limb. The condition occurs spontaneously or following trauma e.g. a sprain or fracture, but the pain in CRPS exceeds the injury caused by the trauma and continues after the original injury disappear (McCabe et al., 2003; Moseley, 2004a). As for PLP and stroke, reorganisation in the brain is thought to cause CRPS, with representation of the affected area in primary somatosensory cortex being smaller compared to the unaffected areas, MVF is thought to work by changing back these maladaptive reorganisations (Moseley, 2004a; Sato et al., 2010) - see section 2.2.6 for elaboration of the mechanisms behind MVFs effect.

Evidence for MVFs effects in treatment of CRPS has been with mixed results. In subjects with early CRPS (less than eight weeks) MVF has showed an analgesic effect and improved motor functioning, whereas treatment of patients with intermediate CRPS (five months to one year) do not seem to have an immediately analgesic effect, but improves motor functioning by easing stiffness in the affected limb (McCabe et al., 2003). MVF do not seem to help chronic CRPS patients (more than two years), and treatment has been stopped before time because MVF use elicited intolerable pain (McCabe et al., 2003; Moseley, 2004a). But when included in Moseley´s (2004a; 2004b) graded motor imagery program (see section 2.2.3 below) where minimum of movement of the affected limb is included, MVF seems to have an analgesic effect on chronic CRPS.

MVF has also been tested in rehabilitation and treatment after wrist fractures and hand surgery (Altschuler & Hu, 2008; Ramachandran & Altschuler, 2009; Rosén & Lundborg, 2005), fibromyalgia (Ramachandran & Seckel, 2010) and cerebral palsy (Feltham, Ledebt, Deconinck & Savelsbergh, 2010) with promising but not conclusive results.

2.2.3 Graded motor imagery

An advanced form of MVF has been developed in form of graded motor imagery. This treatment program, developed by Butler (2009b) and Moseley (2004a; 2004b), combines traditional mirror therapy with; *laterality*, the ability to recognize if a body part belongs to the left or right side, and *motor imagery*, mental rehearsal of acts without actually accomplishing movements. The program was developed, because some patients might not benefit from MVF, because the treatment elicits too much pain. Actually just imagining moving the affected limb increases pain in some patients (Moseley et al., 2008). The idea behind the graded motor imagery program is to avoid increasing pain by avoiding movement.

The theory behind the graded program is that; when recognising if a picture displays a left or a right hand, a pre-conscious estimation guides the choice of mentally moving either left or right hand to the pictured position, to confirm the choice. Often the first estimation is correct (Parsons, 2001). When imaging a movement the same neural structures are activated as if the movement was actually performed. Therefore, laterality and mental motor imagery depends on the same neural circuits as that is involved in motor control (Jeannerod, 2001; Nico, Daprati, Rigal, Parsons & Sirigu, 2004). Through the mental motor imagery program, it might be possible to rehabilitate motor executing circuits (Moseley, 2004a; Moseley, 2006; Stevens & Stoykov, 2003).

This relationship between laterality and the motor executing circuits inspired to use laterality as a measurement for the effectiveness of MVF, which will be elaborated in section 5.3.1.

2.2.4 Lack of evidence

In the theory section above, it has been described which groups of patients has been tried to treat with MVF, but the effectiveness has been questioned and it seems like the current evidence is still limited (Ezendam, Bongers & Jannink, 2009; Rothgangel et al., 2010; Seidel, Kasprian, Sycha & Auff, 2009). Rothgangel et al. (2011) concludes in a systematic literature review of MVF conducted as long-term treatment (more than two interventions) that the quality of evidence regarding MVF as intervention to CRPS and PLP is low, and that quality of evidence regarding MVF used to recovery of arm functioning is only moderate. Ezendam et al. (2009) concludes in another literature review that MVF shows promising results for CRPS1 and stroke patients, but other areas do not provide sufficient methodological quality for the evidence to be determined.

Rothgangel et al. (2010) sums up the critic:

> "studies are heterogenous in design, use different measures at different times and often includes small numbers of unrepresentative patients. In addition, important clinical aspects of MT [mirror therapy] interventions such as a detailed description of the treatment protocol and possible side effects are only insufficiently addressed" (p.11).

According to this quotation, the current study seems very relevant since it investigates the effects of differences in treatment application.

2.2.5 Adverse effects

As it appears in the above quotation from Rothgangel et al. (2010) the adverse effects from MVF are not addressed in many studies, but the few studies, that has investigated it, seems relevant to describe in order to avoid causing any unpleasant experiences for the participants in the current study.

Casale, Damian & Rosali (2009) investigated these possible negative effects from MVF. In a sample of 33 lower-limb amputees, only four did not report negative side effects from MVF, and only four completed the prescribed 15 days of treatment. The remaining group mainly reported feelings of dizziness, uneasiness and confusion.

The results seems worrisome, but might be caused by the patients simultaneously engaged in prosthesis training. Prosthesis training and the methodology behind rehabilitation are different from that of MVF. The incorporation of the prosthesis into the body image, and the acceptance and coping with the limb loss contradict and conflict the methodologies of MVF, where it is tried to trick the brain into thinking the missing limb can be moved as before the amputation (Casale et al., 2009). The results from Casale et al. (2009) also dispute with other investigations of the effects of MVF to amputees (Brodie et al., 2007; Chan et al., 2007; Ramachandran et.al., 1995), therefore the preliminary conclusion might be that MVF and prosthesis training should not be done simultaneously.

However another study also suggested MVF to be able to cause unpleasant feelings. Incongruent movements – moving one arm up and the other down – during MVF caused healthy subjects to report feelings of uneasiness and unpleasantness. The reported symptoms included anomalous sensory symptoms like numbness, a feeling like pins and needles in the hidden limb, moderate aching or pain, changes in temperature and limb weight and nausea, dizziness and disorientation (McCabe et al., 2005). This suggests that only congruent movements should be used in MVF in order to avoid negative side effects. However it should be noted that the results from McCabe et al. (2005) are not statistical analyzed, and that congruent movements also elicited unpleasant feelings in some participants.

Disagreements exists on if MVF can be done with unimanual movements (Butler, 2009a; Moseley, 2004b) or only with bimanual movements (McCabe, 2010), but in the current study the participants will be instructed to use bimanual congruent movements in order to try to make sure no negative side effects from MVF is experienced.

2.2.6 Mechanisms behind MVFs effect

After introducing the current studies of MVF and the limitations in the current evidence, it seems in its place to also describe the mechanisms behind MVFs effect. In order to examine which patients will benefit from MVF, why inter-variability exists and how the treatment is improved, it is necessary to understand the mechanisms responsible for the effects of MVF. Therefore the following section will provide a description of the main suggestions of the mechanisms behind MVFs effect. In the "discussion" section 7.0, these mechanisms will be discussed in relation to the results from the current experiment.

There are presented many explanations for the underlying mechanisms for MVFs effect and much disagreement exist on which is the main mechanisms. Also, it has even been suggested that different mechanisms underlie the effects of MVF in treatment of different groups of patients (Ezendam et al., 2009; Michielsen et al., 2011). The only thing there seems to be agreed upon is that the underlying mechanisms for MVF are not definitely clarified (Chan et al., 2007; McCabe, 2010; Michielsen et al., 2010; Michielsen et al., 2011; Ramachandran & Altschuler, 2009; Rothgangel et al., 2010; Sathian et al., 2000; Sato et al., 2010, p. 627; Yavuzer et al., 2008).

Distraction

MVF has been suggested to work by distracting the patient from the painful limb, because the patient has to focus on the mirror image and meanwhile attempt to ignore the affected painful limb. When subjects feel ownership of the mirror reflection, they are able to disconnect from the affected limb, which reduce sensory input and pain (Brodie et al., 2007; McCabe, 2010; Sato et al., 2010). Thereby MVF might help by creating an illusion of pain free movement in the affected limb, which gives the patients a recall of performance ability without pain and make them less anxious of moving the limb. The increased movement causes the rehabilitation to progress (McCabe, 2010; Moseley, 2004b).

Attention

An opposing theory suggests MVF works because patients have to pay more attention to the affected limb during MVF. In stroke and CRPS the affected limb often become neglected and disowned, which causes the limb to become objectively cooler with information. During MVF patients are forced to engage with their neglected limb, which improves sensory perception leading to improved ownership of the limb (McCabe, 2010; Moseley, 2004a). Ownership and sensory perception are seen as essential to recovery of function (McCabe, 2010).

This theory is supported by a study where healthy subjects experienced a reduction in pain if they observed their hand while it was induced with a painful infrared laser. The analgesic effect was specific to viewing one´s own hand, and did not work while observing another person´s hand or an object (Longo et al., 2009). Amputees, who viewed another person´s hand being massaged or scratched, experienced a reduction in PLP, so the effects might be different after amputation (Weeks & Tsao, 2010).

Unlearn learned disuse

In relation to the theory of attention as the working mechanism in MVFs effect is the theory of unlearning a learned disuse, where the effects rely on the forced use of the affected limb. Some part of a paralysis in post-stroke patients might be caused by a *learned disuse*, where a long period of non-use causes a reversible loss of neural functioning. Likewise amputees might lose voluntary control of their phantom, because they stop trying to move their phantom limb. The theory of learned disuse was originally formulated by Taub (Ramachandran & Altschuler, 2009). From this perspective MVF should work by forcing the patient to use their affected limb, and then try to return the effects of learned non-use (Brodie et al., 2007; Moseley, 2004a).

This MVF differs from the therapeutic intervention proposed by Taub, who developed *constrained induced therapy* (CI). CI for hemiparesis involves the patient unaffected arm being restricted from use by a mitt forcing the patient to try to use the paralysed arm leading to an improvement in functioning and mobility (Taub, Uswatte & Pidikiti, 1999). No visual feedback is used (Ramachandran & Altschuler, 2009, p. 1696). Taubs theory of learned non-use could possibly explain some of the problems in amputees, CRPS and post-stroke patients. But since MVF is found to be twice as effective in creating an experience of control and movement in phantom limbs compared to movement without a mirror the effects must be caused by other mechanisms than just repeated use of the affected limb (Brodie et al., 2007; McCabe, 2010; Ramachandran & Rogers-Ramachandran, 1996; Stevens & Stoykov, 2003).

Reversing cortical reorganisations

The explanation for MVFs effect, which most articles agree upon, is that the effect might be ascribed to a reversing of the cortical reorganisations seen in groups of patients treated with MVF (Altschuler et al., 1999; McCabe, 2010; McCabe et al., 2003; Mercier & Sirigu, 2009; Moseley, 2004a; Ramachandran & Altschuler, 2009). As described in the above sections 2.1.3 and 2.2.2, in amputees, CRPS and post-stroke patient's reorganisations can be seen in the cortex. The changes involve alterations in both somatosensory and motor representations of the body e.g. the body image are affected as for example when patients suffering from CRPS experience the affected limbs as being bigger that it actually is. Pain intensity correlates with cortical reorganisations (McCabe, 2010; Moseley, Parsons, & Spence, 2008) as well as less sensorimotor activation correlates with higher degree of pain (McCabe, 2010). Corrections of a mismatch between motor intentions and sensory feedback, activation of mirror neurons, and recruitment of ipsilateral pathways have been proposed to reverse the reorganisations. These will be described in the following.

Correction of a mismatch and creation of a coherent body image

Symptoms in patients with PLP, paralysis following stroke and CRPS might be caused by a disruption of sensory feedback in the motor control system.

Before executing an action, the motor control system[3] makes a prediction (efference copy) about the sensory consequence of that action in order to prepare the body for further activity and to ensure the safety of the individual. After each movement, the prediction is matched with the actual outcome, and the motor control system is modified/updated (McCabe, 2010; McCabe, Haigh, Halligan & Blake, 2005).

[3] The motor control system is used as a term for the system planning, controlling, executing and evaluating movements (Shumway-Cook & Woollacott, 2001). This system also controls mental motor imagery and hand laterality (see section 5.3.1 for elaboration).

In PLP, stroke and CRPS patients the sensory information from the affected limb becomes disrupted due to the injury. Therefore a mismatch is created between the motor intentions send to the affected limb, and the receiving sensory information from that limb. The predicted outcome of a given action will therefore not match the sensory feedback, which yields an error signal (Giraux & Sirigu, 2003; McCabe, 2010). This error signal might be perceived as pain, because pain serves as an alarm system, which warns the person that something is wrong. This might be what causes pain in PLP and CRPS (McCabe & Blake, 2007). Besides yielding an error signal, the reduction in sensory feedback from the affected limb (se section above) do potentially impair the motor control system, because the motor control system is not proper updated. This results in an aggravated disruption of motor output (McCabe, 2010). McCabe et al. (2005) investigated how incongruence influenced healthy subjects (section 2.2.5) and found evidence for the theory that many symptoms in PLP, stroke and CRPS are created because of incongruence between motor intentions and sensory feedback.

MVF works by providing false but congruent sensory feedback from the affected limb, thereby correcting the mismatch between motor intentions and sensory feedback, which in return result in a proper update of the motor control system (Altschuler et al., 1999; McCabe, 2010; McCabe et al., 2003; Mercier & Sirigu, 2009; Ramachandran & Altschuler, 2009) which should translate to an effect of more controlled and faster movements (Stevens & Stoykov, 2003, p. 1092).

When the mismatch between motor intention and sensory feedback is resolved, it is possible to recreate a *coherent body image* (Casale et al., 2009; Lotze & Moseley, 2007; Murray et al., 2007).

Mirror neurons

The effects of MVF might also be due to the activation of mirror neurons. It has both been stated as a mechanism in itself (Sütbeyaz et al., 2000; Yavuzer et al., 2008) and as the underlying effect of creating a coherent body image (Casale et al., 2009).

Mirror neurons were originally discovered in the premotor cortex of monkeys (Rizzolatti, Fadiga, Fogassi & Gallese, 1996), but research has demonstrated the same mirror neuron system in humans (Buccion, Binkofski & Riggio, 2004; Rizzolatti & Sinigaglia, 2006). Mirror neurons are a class of neurons which are activated during observation of action, visualization of action and execution of the same action. When focusing on the mirror reflection of movements of an unaffected limb, the hemisphere ipsilateral to the unaffected limb becomes activated because of this mirror neuron activation. Because the hemispheres control the motor output of the contralateral side of the body, this activation facilitates learning the observed action and enhances motor evoked potentials to perform the action with the affected limb (Cattaneo & Rizzolatti, 2009). When the two hands or legs are moved during MVF, the mirror neuron system probably induce a fine tuning of the motor commands, which accelerate recovery of functioning (Chan et al., 2007; Eng et al., 2007; Moseley et al., 2008).

Recruitment of ipsilateral pathways

Recruitment of ipsilateral pathways has also been put forward as an explanation for the underlying neurological mechanisms of MVF. Inter-manual referral, where sensory stimulation of the unaffected hand produce referred sensations on hidden affected hand, has been seen as support for the existence of ipsilateral connections between the hand representations in the brain. Hence activation of the one hand activates the somatosensory area in the contralateral hemisphere of the brain, and at the same time symmetrical-points in the ipsilateral hemisphere are activated through unknown commissural pathways (Acerra & Moseley, 2005; Ramachandran & Hirstein, 1994; Ramachandran et al., 1995). In normal individuals this might be too weak to express itself, but if the body image is disturbed the signals might be strengthened or \`countersignals´ are missing therefore stimulation potentially reach threshold and stimulation on the one hand is also felt on the other missing or affected hand (Rogers-Ramachandran & Cobb, 1995).

Evidence for ipsilateral activation was found in a study, where viewing movements in a mirror enhanced ipsilateral M1 activity compared to observing one hand performing movements without a mirror (Garry, Loftus & Summer, 2005). If mirror neurons or ipsilateral pathways are responsible for this activation remains to be explored.

In sum; relative few attempts have been made to investigate the underlying mechanisms for MVFs effect (Michielsen et al., 2011). The mechanisms presented in the above section has both described as opposing to each other (e.g. Yavuzer et al., 2008), and as dependent on each other, e.g. the activation of mirror neurons might play an active part in reducing a mismatch between motor intention and sensory feedback (e.g. Casale et al., 2009). Despite the agreement that the mechanisms underlying the effects from MVF are not definitely clarified, it is the same mechanisms that reoccur in the literature. This suggests that there after all is some agreement on the mechanisms.

2.2.7 Summary of current evidence

By now it should be evident that MVF has showed promising results in treatment of different groups of patients, most prominent in amputees, stroke patients and people suffering from CRPS.

A few reverse effects have been reported, but generally MVF seem very safe to use. The level of methodological value is considered low in many studies, which calls for more experiments of MVFs effects. Also the mechanisms by which MVF seems to work needs to be clarified in order to be able the improve MVF treatment. After describing the ground from which MVF developed, and the current state of evidence of MVF treatment, it seems appropriate to narrow down the focus on specific features in MVF. The purpose of the following section is to outline some areas which the above literature review has showed needs investigation and which I find interesting to investigate.

3.0 Exploration

So far the background for MVFs development, the current evidence regarding, which groups of patients benefit from the treatment, and the mechanisms behind MVF have been described. The next section will focus on areas, which I find interesting to explore. Two main themes will be addressed; which tasks and movements are used during MVF, and which influence do feelings of ownership of the mirror reflection have.

3.1 Different responses to MVF

Despite the promising results from studies with MVF some patients did not gain benefit from the therapy (Brodie et al., 2007; Giraux & Sirigu, 2003; Mercier & Sirigu, 2009; Ramachandran & Altschuler, 2009; Sato et al., 2010). Already in the first study Ramachandran et al. (1995) found some patients who did not respond to MVF, and it was written "*the procedure may not work on all patients and the reasons for the variability remain to be explored*" (p. 489). This quotation exemplifies the need to explore variability between patients benefit from MVF, but most research have primarily been concerned with proving MVFs general effectiveness. In the following a few attempts to explain inter-variability in patients' responses to MVF will be outlined.

Differences in patients' proceeds with MVF have been suggested to be due to clinical characteristics of the patients. Sumitani et al. (2008) studied which influence pain intensity had on the effectiveness of MVF. In 22 patients with deafferentation pain they found MVF more useful in treating deep level pain compared to superficial pain, but concluded that overall MVF had an analgesic effect in patients with both upper and lower affected limbs. From a single case Sathian et al. (2000) suggests MVF might be more efficient in patients with somatosensory deficit, because they have to rely vision to guide movement. This suggests clinical characteristics being the reason for variability. Also neurological differences might explain inter-variability as it can be outlined in the following quotation. "*The fact that not all amputees were subject to the effect may be due to a complex interaction between visual areas and the reorganized motor and somatosensory areas that result from an acquired limb loss*" (Brodie et al., 2007, p. 435). In stroke patients differences in the location of brain damages and the extent of the damage, or the degree of cortical reorganisations in PLP and CRPS might explain differences in to MVF.

The above points to clinical characteristics as causing different responses to MVF, but of the above mentioned studies only Sumitani et al. (2008) tried to investigate the differences systematic. Also Mercier & Sirigu (2009) looked for factors explaining inter-subject variability, and found no relationship between long-term pain relief and time since injury, and no relationship between immediate pain relief during MVF and long-term pain relief. The patients in this experiment were quite equal in their expressions of PLP characteristics, so this was not thought to influence responses to MVF.

When clinical characteristics did not seem to explain inter-variability Mercier & Sirigu (2009) looked into patients subjective expressions during treatment. The patients who responded well to the treatment often reported other somatosensory illusions. From that it was hypothesised that differences in patient benefits from MVF might be due to differences in the susceptibility to believe in the visual illusion (Mercier & Sirigu, 2007). McCabe et al. (2005) support this view, and hypothesize differences in healthy individuals experiences during MVF might be caused by innate susceptibility to the mirror illusion, with some individuals being more vulnerable to detecting sensation arising from MVF. I will return to this in section 3.4.

It is difficult to conclude anything on clinical characteristics influence on MVF treatment. Unfortunately only few studies provide information on patients' characteristics, which makes it difficult to draw any firm conclusions on which patients will benefit from MVF (Rothgangel et al., 2010). The exact differences between patients especially which cortical reorganisations follow/cause their symptoms is difficult to measure, and therefore also difficult to investigate the influence from. In the current experiment, the use of healthy subjects should reduce the influence from such clinical characteristics, and it will be tried to see if other characteristics, such as age and gender, influence the effects of MVF.

In the next section, I will suggest that some differences in patients' proceeds might arise because of differences in application of MVF.

3.2 Application of MVF

The aim of this study is to investigate if it is possible to identify any influencing variables on the effectiveness of MVF. A possibility is to look into how the treatment is conducted in practice and if the practical approach to MVF could be changed. Rothgangel et al. (2010) express a need to clarify clinical aspects of MVF. In their review of the effectiveness of MVF it was not possible to find treatment factors which increase or decrease the effectiveness of MVF, because the studies did not specify treatment characteristic. For the same reason it has not been possible to write clinical protocols of how to use MVF. Often articles do not even mention which tasks they use in treatment with MVF, e.g., Chan et al (2007), Dohle et al., (2009) and Ramachandran et al. (1995). The following section will focus on how to apply MVF; for how long should the treatment persist and what exercises should be used during MVF. This section will also be used to provide guidelines for the application of MVF in the current study.

One problem in MVF treatment is, that there is not developed an evidence-based protocol for the treatment in the clinical setting. The protocols available are built on practical experiences, which cause different guidelines provided by different therapists (McCabe, 2010; Rothgangel et al., 2010). Few attempts have been made to write clinical protocols, but guidelines are easily accessible at the internet, for example at YouTube.com (See Butler, 2009a; Lieberman, 2009).

Advises given for the clinical setting are, that MVF should be done in a quiet environment to enable complete concentration on the mirror reflection, while doing the therapy. The patient should sit comfortable in front of the mirror; look at the mirror reflection at all times during the therapy and try to forget about the affected hand. Any identifying items should be removed from the limbs liken pieces of jewels, watches and sleeves or trousers should be pulled up (Butler, 2009a; McCabe, 2010; Pedersen, 2011a).

It has been put forward, that the composition of movements used during MVF should fit individual needs (Butler, 2009a; Pedersen, 2011a). Examples of tasks used in MVF could be; extension/flexion of the fingers and wrist, turning hands up and down, moving fingers like playing the piano, touching fingers to thumb one at a time or squeeze the hands together. It is also suggested to use tools; small balls, a scissor and the like (Butler, 2009a; Lieberman, 2009; Pedersen, 2011a). The specific movements are by some seen as unimportant; "*The actual manner of movements appears not to matter as long as it is bilateral and synchronized*" (McCabe, 2010, p. 6). As this citing tell, McCabe estimate the importance of moving both hands at all times, but sees the specific movements as not influencing the effectiveness of MVF. I will return to the discussion in the next section 3.3. The reason, it is advised to use bilateral synchronized movement, is because moving the hand incongruently or only moving the hand, which is mirrored, might exacerbate symptoms in patients (McCabe, 2010). This reason builds up on the experiment exploring, how a mismatch between visual information and proprioception[4] affected healthy individuals (McCabe et al., 2005; see section 2.2.4). Not everybody shares this opinion, some therapists states that unilateral movements with the unaffected hand is good as a step before moving both hands, if the affected hand is not able to move at first, either because it evokes too much pain or because of movement disability (Butler, 2009a; Weinberger, 2010).

[4] Proprioception is the perception of the relative position of the body, limbs and the head and their position in relation to each other (Kolb & Whishaw, 2009, p.G-27).

Also the duration of MVF is not definitely clarified, but majority of studies use the mirror for weeks (Altschuler et al., 1999; Eng et al., 2007; Moseley, 2004b; Ramachandran & Hirstein, 1998; Sathian et al., 2000; Steven & Stoykov, 2003; Yavuzer et al, 2008). But immediate effects of the MVF can be seen as when the mirror treatment has an immediate analgesic effect (Brodie et al., 2007; McCabe et al., 2003; Ramachandran et al., 1995). In McCabe et al. (2005) mirror effects were observed in healthy individuals after only 20 seconds of exposure to MVF. The length of the sessions deviate in each experiment, but Butler (2009a) advises the session lasts as long as the patient can concentrate, e.g. if five minutes is the limit, then stop after that.

In sum, there seems to be different opinions of how to conduct MVF, which might have an impact on treatment outcome. In the current study the guidelines for the clinical setting; quiet environment, sit comfortable and look at the mirror reflection at all times will be followed. It has been chosen to only focus on the immediate effects from MVF; therefore the MVF will be conducted in short sessions of five to seven minutes.

The aim of the current study is to investigate, factors influencing the effectiveness of MVF and how MVF treatment can be improved, but all aspects cannot be investigated. In the following section, the theoretical argumentation for the selection of tasks and ownership feelings as the area of investigation will be outlined.

3.3 Complex tasks

Above it is mentioned, that the specific movements used in MVF do not influence the effectiveness of the treatment. I will try to argue against that.

As described in section 2.2.6, one underlying mechanisms of MVFs effect could be to remove a mismatch between motor commands and visual and proprioceptive feedback. This should lead to a restoration of the motor control system, where a proper visual and proprioceptive input lead to a coherent body image, which in turn results in a prober updating of the motor control system (McCabe, 2010). As Stevens & Stoykov (2003) puts it "*performance improvement* [after MVF] *are linked to a priming of the motor system at a central command level, which translate to a downstream effect of more controlled and faster movements*" (p. 1092). This implies that reduced functioning is partly caused by a disturbance in the motor system, in the circuits mediating between motor intentions and motor execution (ibid.). If this is the case, then MVF should try to activate cortical areas involved in both motor intention and execution.

Different cortical areas are activated during different parts of action execution and in addition different areas are activated due to the demands of the task performed. The primary areas involved in action execution are primary motor cortex, premotor cortex, frontal cortex and somatosensory cortex (Kolb & Whishaw, 2009).

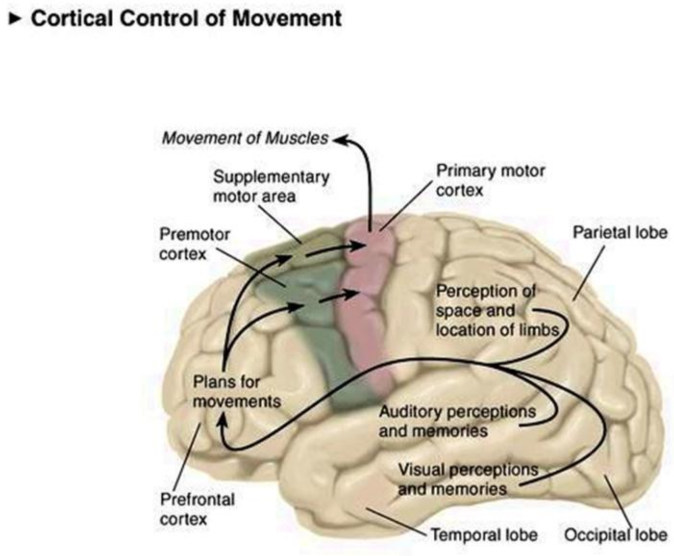

Figure 2: *Many areas are active in motor execution. The picture provides a review of some of the most prominent. Posterior cortex provides sensory information to the frontal cortex. In the frontal cortex plans for movements are generated, from there information travels to the premotor cortex for movements sequences to be organized. Finally motor cortex produces the movements (Kolb & Whishaw, 2009, p.225).*

Roland (2003) investigated cerebral blood flow as an indication for neural activity during tasks of different complexity; repetitive finger tapping, sequence of finger movements, solving a maze by navigating a finger. During repetitive finger taping blood flow in somatosensory and primary motor areas increased, and when the subject performed a sequence of finger movement's blood flow increased in the primary premotor cortex as well. When navigating out of a maze by using the finger, blood flow also increased in prefrontal cortex and in parietal- and temporal regions. This reflects the requirements in moving through a maze; i.e. coordinating movements in pursuit of a goal (Roland, 2003). If motor performance is inhibited, because of disturbances in the motor control system then MVF should aim at restore information flow in the motor control system. As I see it, due to the above, this might imply that all areas involved in the motor control system should be activated during MVF. One way to reassure this is to use complex tasks which are cognitive demanding and not solved by automatic performance.

A related suggestion is proposed by Mercier & Sirigu (200), who investigated the differences in patient proceeds with MVF. In their study, patients, who experienced a reduction in PLP during MVF, all expressed some trouble with moving the phantom limb. They had to make an effort to move it. Opposite the patient, which could easily perform the movements did not benefit from MVF. These results were comparable to fMRI research which revealed that patient who did benefit from MVF also showed increased activation in motor areas (Giraux & Sirigu, 2003). This leads Mercier & Sirigu (2009) to the hypothesis that movement observation led to motor cortex activation in some patients but failed to do so in others, and in addition that expressions of effort to move the phantom could be an indication for this activation.

Build up on the experiments by Roland (2003) and Mercier & Sirigu (2009); I have come to think that the movements and tasks used in MVF might influence treatment effects.

As far as I am concerned, no studies have explored the differences between complex and simple tasks during MVF, but variations in cognitive demanding task can be found. Using complex tasks in treatment should help by keeping the patients motivation to engage in the treatment high (Eng et al., 2007; Sato et al., 2010). Eng et al. (2007) used tasks which were challenging but possible to finish to motivate the patients. The same concept is found in Stevens & Stoykovs (2003) study. In a four weeks program of rehabilitation of hemiparesis, they gradually increased the complexity of the tasks used, so the patients were challenged at all time. At the end of the treatment period, they drew geometrical shapes in front of the mirror. Most studies which have included complex goal oriented tasks use some kind of virtual reality systems (Eng et al., 2007; Murray et al., 2007; Sato et al., 2010). These systems gives more possibilities to do advanced tasks, because they are not limited by the narrow spatial dimension provided by a single mirror and are not restricted to have the patient seated in a relative fixed position in order to only see the mirror reflection and not the limb hidden behind it (Murray et al., 2007, p. 1465). Examples of tasks used in virtual reality systems, which I defined as complex, include different kinds of object manipulation; hitting, catching, grasping, transferring, placing (Eng et al., 2007; Murray et al., 2007; Sato et al., 2010).

When you do different movements of different complexity you activate different brain areas, therefore I thought it might be interesting to compare movements of different complexity. The above discussion has led me to the hypothesis, that complex tasks will improve the effectiveness of MVF.

3.4 Ownership

In the following section, the theoretical ground for why ownership feelings of the mirror reflection are important will be presented, followed by reflections of the problems in using ownership as a measure of MVF effectiveness.

A very important aspect of self-consciousness is our body and the feeling that our body is part of our self. A body perception disorder like neglect, where people are not consciously aware of a certain limb or one side of their body, illustrate the importance of feeling ownership of our body (Ehrsson et al., 2007; Ehrsson et al., 2004; Slater, Perez-Marcos, Ehrsson & Sanchez-Vives, 2008). Despite playing such an important role, ownership or the body image can easily be manipulated, as described in section 2.1.4. An example of this manipulation is the rubber hand experiment (Botvinick & Cohen, 1998; Ehrsson, Holmes & Passingham, 2005; Guterstam, Petkova & Ehrsson, 2011). MVF takes advantage of the ability to come to perceive ownership of the mirror reflection.

A possible explanation for differences in patient´s proceeds through MVF could be not everybody comes to perceive ownership of the mirror image. It has been pointed out that ownership of the mirror image is necessary to achieve any effect from the mirror (Eng et al, 2007; McCabe, 2010; Mercier & Sirigu, 2007). "S*ubjects´ ability to believe in the visual illusion of the mirrored limb may determine the effectiveness of MVF*" (McCabe, 2010, p. 4). This suggestion relay up on the notion in the Rubber Hand Illusion that perceived ownership of the rubber hand is necessary to causes a proprioceptive drift toward the rubber hand (Botvinick & Cohen, 1998).

To achieve ownership of the mirror reflection a good alignment between mirror image and proximal limb is required (Guterstam et al., 2011; Mercier & Sirigu, 2007). As well as a good alignment between motor commands and the observed visual movements are important to perceive ownership (Brodie et al., 2007). Relying on observations from the RHI paradigm, there need to be synchrony in applied stimuli on the rubber hand (mirror reflection) and the hidden hand (Botvinick & Cohen, 1998; Guterstam et al., 2011). This means the appearance of the mirror reflection should be similar to the hand behind the mirror. To do this jewellery, watches and other identifying items, which might interfere with the ability to believe in the illusion, should be removed as described by McCabe (2010). Also patients should be instructed to try to believe the mirror image really was their real limb and that it is important only to use the mirror as long as the patient can concentrate on the mirror reflection.

Much research on ownership has been carried out in RHI regime and less in MVF and often conclusion from RHI are transferred to MVF. How much influence does ownership have on the effectiveness of MVF? For example are identical appearance of the mirror reflection and the real limb important. A few studies question the importance of ownership in MVF. Sato et al. (2010) describe the virtual image used in their study did not look like the real arm, but it did not seem to influence MVF. Therefore Sato et al. (2010) questions the importance of ownership. The same does Brodie et al. (2007) and suggest the activation of mirror neurons is responsible for the effects achieved in MVF – and not necessarily feelings of ownership.

The missing investigation of ownerships influence in MVF is problematic, because expressions of ownership of the mirror reflection are used as criteria for MVF has worked (Longo et al., 2009; Mancini et al., 2011). Together with the suggestions that different abilities to believe in the mirror illusion may account for variability's in responses to MVF (McCabe, 2010; Mercier & Sirigu, 2009), it seems to be important to investigate if the emphasise on ownership is reasonable.

Because MVF might work by the same ability to incorporate objects into the body image, as the rubber hand paradigm, the hypothesis stated in the current study will be that feelings of ownership improve the effectiveness of MVF.

3.5 Sense of agency – a part of ownership?

The next section will provide arguments that ownership might not be divided from the sense of agency, and therefore agency might play an equally important part in MVF as ownership. As described in the definitions, a sense of agency is here defined as the feeling that you are in control of your movement, is able to generate action and create changes in your surroundings (Gallagher, 2000, p.15).

The concepts of agency and ownership might not be easily divided, and therefore if ownership influences MVF effects, agency might also influence MVF. In an attempt to clarify the notions of bodily representations Gallese & Sinigalia (2010) have tried to describe the core or minimal self, build upon the belief that even "*after stripping away all unessential features there will be a basic, immediate and primitive something that we are willing to call a self*" (p. 746). This minimal sense of self is a sense of bodily self as power for actions, and even though this sense of self is stripped for any unessential features both agency and ownership are important components of this bodily self (p.746-750). Motor intentionality is the step before action and this intentionality is tied together with the body experiencing itself as a bodily self with a range of possibilities to perform different actions. To be able to perform actions, we need to know where our body is and what possibilities for action we have. As an example people with neglect do not use the arm they do not think they have. On the other hand Gallese and Sinigalia (2010) argue that ownership is dependent on action. This conclusion is drawn from the RHI where for the illusion to occur the dummy hand needs to be positioned in a place compatible with the power for action intrinsic to the body image. Opposite it is found that physical similarities between the rubber hand and the real hand do not affect RHI, which leads Gallese & Sinigalia (2010) to the conclusion that ownership is not merely dependent on visual and proprioceptive information, but are conditioned by the possibility to perform actions with a given limb. Therefore to be able to perceive ownership of the mirror image in MVF, there also needs to be a sense of agency; that you are in control of the movements in the mirror reflection. The model of the minimal sense of self is useful in the understanding and acceptance of why both agency and ownership could be essential components of the mirror illusion.

Experimentally a sense of agency has proved to affect the rubber hand illusion. Tsakiris, Prabhu & Haggard (2006) stated that during active movements the proprioceptive drift towards the rubber hand was smaller, but did affect more of the hand, compared to the passive condition where the proprioceptive drift were only felt for the stimulated finger. It was concluded that "*the motor sense of agency integrates distinct body parts into a coherent, unified awareness of the body*" (ibid., p. 423). The reason for this might be that in S1 do the receptive field of neurons correspond to a quite well-defined skin area, whereas the primary motor areas correspond to groups of muscles and movement synergies M1 (ibid., p. 424). Therefore when moving the hands more than just looking at them in MVF, the illusion might be perceived as covering a greater part of the limb. This seen in relation to the suggested mechanisms in MVF is to create coherent body image, a sense of agency might be important for MVFs effectiveness.

A sense of agency might also have an influence on the effectiveness of MVF independent of ownership feelings. As described in section 3.4, Sato et al. (2010) did not find the physical appearance to affect the effectiveness of MVF, which might point to ownership being less important.

Therefore in addition to investigate if ownership feelings of the mirror reflection influence MVF effects, also feelings of agency will be addressed in the current study. It will be assumed that feelings of agency of the mirror reflection will improve the effectiveness of MVF.

3.6 Summary

The main themes in the current study will be on tasks, ownership – and agency feelings influence on MVF efficacy.

As described in section 3.3, complex task like solving a maze activates more areas of the motor control system. MVFs effect has been proposed to rely on a restoration of the information flow in the motor control system, which support the idea that complex task might improve the effects of MVF because more areas of cortex is involved in complex tasks compared to simple tasks.

In addition I want to investigate how differences in perceived ownership and agency influence MVF outcome. In experiments with the rubber hand the subjects needs to feel ownership of the rubber hand in order to experience a proprioceptive drift towards the rubber hand (Botvinick & Cohen, 1998). This has been applied to MVF, and it is assumed that to be able to improve motor functioning or experience an analgesic effect from MVF the patient has to perceive ownership of the mirror reflection. This has as far as I am concerned not been experimentally tested in the mirror illusion.

Because ownership feelings might depend on the feeling agency; i.e. that you are able to control and move the mirror image this will also be investigated. Even though it has only been investigated, that ownership is important for the rubber hand illusion to occur, it assumes that ownership do influence MVFs effect positive. Therefore the hypothesis´ will be formulated as one-tailed, assuming a positive relationship between ownership, agency and MVF effects.

Before presenting the hypothesis for the current study, some additional questions, which might influence the MVF effectiveness, will be outlined.

4.1 Additional questions

4.1.1 Gender and baseline laterality

As described in the section 3.1, patients' clinical characteristics might influence the effectiveness of MVF. In the current study only healthy subjects will be included, but the personal characteristics such as age, gender and motor performance abilities might have an influence on the MVF responsiveness.

E.g. using high-density EEG source, differences in male and female responses to the mirror illusion was seen, which suggested that the perceived body image had been affected in males, but not females (Egsgaard, Petrini, Christoffersen & Arendt-Nielsen, in press). The foundation for the investigation was that there is well established evidence that gender differences exist on visuo-spatial tasks. Therefore it seems important to investigate if gender difference will also be evident in the current experiment.

The current study will measure the effects of MVF as differences in hand laterality (see method section 5.3.1 for elaboration). Differences in the baseline measurement could possibly influence the results, e.g. subjects how are not were good at hand laterality might improve more after MVF compared to subjects who are fast to recognize which side hand a picture display. In order to make sure that effect measured is caused by MVF, it will be investigated if laterality prior to the experiment influences the outcome of MVF.

4.1.2 Enlarging mirror

An enlarging mirror is included as part of MVF in the current experiment, because it might have the potential to increase the effect from MVF.

Mancini, Longo, Kammers & Haggard (2010) found that when healthy subjects looked at the hand in an enlarging mirror during painful thermal stimuli, the analgesic effect obtained through the mirror was enhanced, whereas a minifying mirror decreased the effect. In chronic pain states the enlarging mirror might exacerbate pain. Moseley, Parsons & Spence (2008) found that a magnifying mirror increases pain in chronic CRPS and a minifying mirror decreases pain. Ramachandran, Brang & McGeoch (2009) also obtained improved analgesic effects using optical shrinkage, where a minifying mirror caused a phantom limb to be perceived as shrinking and at the same time that pain decreased. This effect could not be achieved with a neutral mirror. The use of a magnifying lense did not influence perceived size or pain in this patient. It was also found that the size at which the hand is viewed alters the mental representation of the hand in healthy subjects (Mancini et al., 2010).

The difference between these studies probably relates to difference in the neurophysiological mechanisms underlying acute and chronic pain (Apkarian, Bushnell, Treede & Zubieta, 2005; Mancini et al., 2010). But the results indicate that the enlarging mirror might have a different impact than a neutral mirror. Therefore it is included in the current study.

In the following section the hypothesis of the current study will be presented.

4.0 Hypotheses

The main hypotheses that will be investigated in the current experiment are formulated as follows:

1) The greatest effects from MVF is achieved using complex tasks
2) High ratings of perceived ownership of the mirror reflection causes enhanced effect of MVF
3) High ratings of perceived agency of the mirror reflection causes enhanced effects of MVF

Additional questions addressed in the current study:

4) Do gender influence MVF effects?
5) Does the use of an enlarging mirror improve MVF treatment compared to using a neutral mirror?
6) Does the baseline score on hand recognition influence the effects from the mirror?

5.0 Methods

The theoretical ground from which MVF evolved has been described and used as foundation to develop the hypotheses for the current study. The next task is to develop the experimental design including the experimental setting, materials and measure instrument in order to investigate the hypothesis best as possible. In the following, the main considerations regarding the experimental design will be described.

5.1 Participants

23 participants (12 males and 11 females, aged 19-38, mean age 25,43 years) volunteer to participate in the study. The participants are recruited at Aalborg University, the occupational therapist school and the nursing school by a poster and by personal request by the experimenter. All participants are informed of the purpose of the study, methods used and data handling when recruited (see appendix 12.1; "deltagerinformation og samtykkeerklæring" in English *Participants information and informed consent*, and 12.2; "forsøgspersoners rettigheder i biomedicinsk forskningsprojekt" in English *Participants right in biomedicine experiments*). All participants should give their informed consent prior to the experiment after they have received information about the study. Participants do not receive any training before participating.

Only healthy subjects are included in the current experiment in order for the results not to be influenced by differences in clinical characteristics such as range of symptoms. Therefore subjects are excluded if they have neurological -, muscular - or psychiatric diseases, and if they have tattoos on the upper limbs. Only right handed participants are included in an attempt to minimize confounding variables. These inclusions criteria's will limit the ability to draw conclusions to groups of patients and left handed people, but it has been considered to be more important to control for confounding variables.

5.2 Ethical considerations

The study is approved by "Den videnskabsetiske Komité for Region Nordjylland" (in English: *The Research etichs Committee of The Northern Denmark Region*) under secondary supervisors, Giselle Christoffersen, ethical approval, case number N-20100031.

The participants are ensured anonymity and no personal identifying information is recorded. They do not receive any misleading information, and are instructed that they can cancel their participation at any time, before and during the experiment. Aim and methods in the experiment are announced prior to the experiment, and the expected results are informed afterwards. They participants are told, that they can contact the undersigned, Nana Nielsen, after the experiment is complete, if any questions about the experiment emerge or any side effect are experienced – side effects should not occur as long as movements are conducted congruently.

5.3 Materials and settings

In the experiment two types of mirrors are used – a normal mirror (45x60 cm) and a concave mirror (2 x magnification), and in the control condition the back of the normal mirror is used.

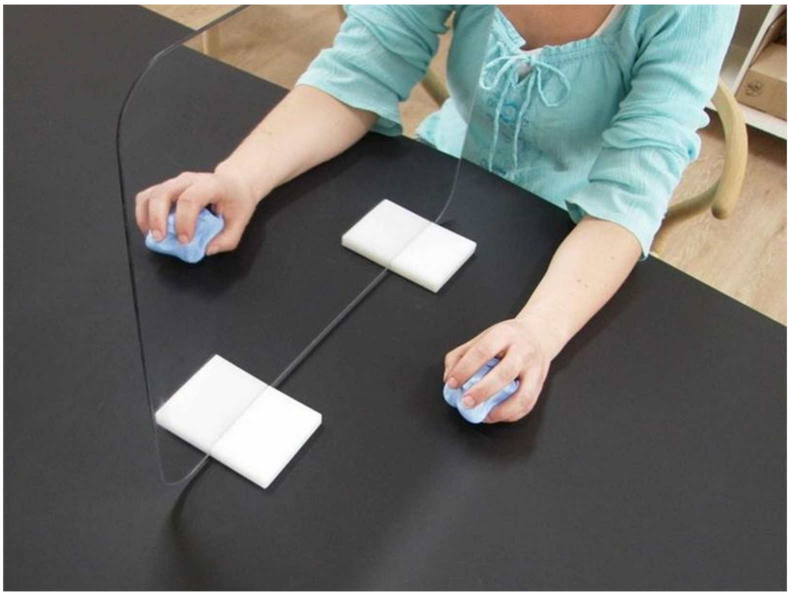

Figure 3: *Picture of the experimental setting.*

The experimental settings are based on the guidelines for MVF use described in section 3.2. In each condition the mirror or back of the mirror is placed vertically in front of the subjects, leaving only one side of the body visible. The mirror is large enough to cover one side of the body. When seated in front of the mirror the participants are asked to adjust the chair so they are able to rest their hands comfortably on the table, with one hand on each side of the mirror. During the mirror conditions the participants have to bend slightly to the right, making them able to watch the mirror reflection of the right hand without seeing their own head in the mirror, and still trying to keep the midline of the body aligned with the mirror. The participants are instructed to try to place the hidden hand, where the reflected hand seems to be. This is done in order to make the mirror reflection superimpose the hidden hand, and through that create the illusion that the mirror reflection belongs to the participant's body. In the no mirror condition the participant have to bend to the left, making them able to watch the left hand without seeing the right hand.

In the enlarging mirror conditions there are a few problems with the setup. The hands should be placed in front of the centre of the mirror in order to achieve the whished enlargement. Therefore two boxes are placed on each side of the mirror, so that the subject can rest their hands on the boxes and then stay at the centre of the mirror. This causes the participants to sit with the arms in a rather uncomfortable position. In addition it is very difficult to see the mirror reflection without bending so much to the right that the face can be seen in the mirror. This also makes it difficult to keep the mirror straight in front of the body's midline, therefore the hidden hand is not exactly placed, where the mirror reflection appears to be.

Materials used in the simple condition are small balls and square cubes. In the complex task conditions puzzle houses, boxes with two different size pearls and 9 different mazes are used. There are two sets off each material; one for each hand.

Inspiration to the tasks in the simple conditions is derived from different videos on the internet, which explains how to do mirror therapy (Butler, 2009a; Lieberman, 2009; Pedersen, 2011a; Weinerberg, 2010). Whereas the inspiration to the complex task builds on Per Roland (2003) experiments, where finishing mazes activate greater areas in cortex compared to tasks such as finger tapping. The mazes were found by a searching "labyrint" (In English *maze*) on Google pictures. Three different mazes are used in each condition with complex tasks. The mazes are ranged into three different levels according to how long time they take to finish without any mirror. This is tested by the experimenter and a person for whom the purpose of the rating were unknown. The three levels are 4-6 seconds, 8-10 seconds and 10-13 seconds. In each complex condition a maze from each of the levels are included as a complex task. The other complex tasks; putting blocks in the right holes in a puzzle house, and moving pearls from one box to another, are regarded as complex due to the definition of complex tasks to be goal directed. Because the cortical activation during these tasks is not stated, these tasks are done first and the mazes are introduced last in the experiment, which should ensure the activation during maze solving will be the one measured afterwards.

After each task the Hand Recognition Test and a questionnaire are administered.

5.3.1 Hand Recognition Test

A Hand Recognition Test (http://recognise.noigroup.com/recognise) is used to test the effect of the mirror illusion. In the test the subject is presented with 30 small video clips presenting right or left hands doing various movements (Figure 4). It is also possible to chose pictures with hands in different positions, but the video clips are chosen, because the hands appear doing different activities, often with tools, and this kind of pictures are more difficult to report (Pedersen, 2011a). Easy recognized pictures will be hands in different positions, but not doing any activities. It is thought that there will be a greater chance of seeing changes in recognition of difficult pictures or videos, rather than easy ones, because the subjects might be as good as possible to recognize the easy pictures from the beginning. In the test the subject has to recognize, if it is a left or right hand displayed. They are instructed to do this as fast as possible, and as correct as possible. The time limit for each picture is set to 5 seconds, and if exceeded a new video clip is presented and the exceeded clip will be recorded as *incorrect*. The test is done on a computer, which calculates the mean laterality to recognition of each hand (response time - RT) and percent correct answers (accuracy). Due to the theoretical argumentation for the use of the hand recognition test (see below), only the RT is thought to reflect the impact from MVF and tasks. Accuracy scores do not measure the impact from MVF, but will reflect if there is a risk the participants have been guessing, and not really tried to estimate which side of hand, they saw. Accuracy scores approximately 50% or below might reflect the participants have been only guessing.

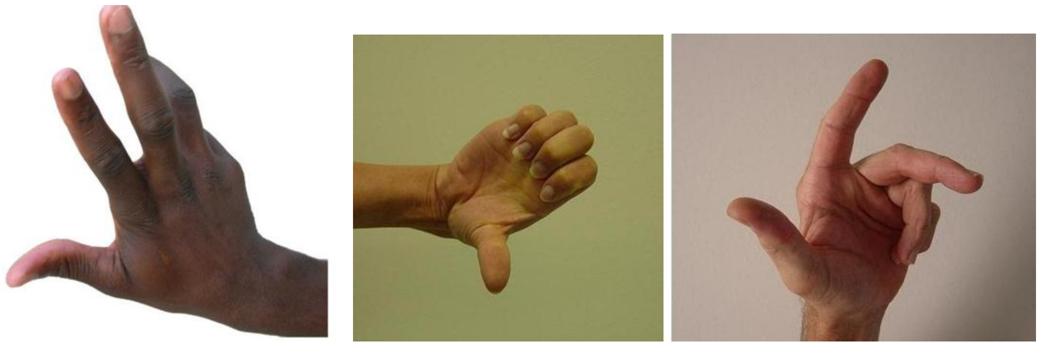

Figure 4: *Examples from the hand recognition test. It shall be determined if the pictured hand belongs to the left or right side of the body. The NOIGroup provides an example of the test at: http://recognise.noigroup.com/recognise.*

The test used in this experiment is developed by the NOI group (http://recognise.noigroup.com/recognise).

5.3.1.1 Theoretical background for the hand recognition test

The theoretical background for why the hand recognition test measures the effects of MVF will be described in the following.

Laterality and motor execution depends on the same neural structures (section 2.2.3) which is why hand recognition can be used as a measurement for the effectiveness of MVF. In order to recognize if a picture displaying a right or a left limb, we have to confirm a pre-conscious estimation by mentally moving our own limb to the picture posture. The more awkward the picture position is, the longer time it takes to mentally move our own limb to the given posture (Parsons, 2001). In addition it is found that mentally moving a limb directly correspond to the time it would actually take to move a limb to the given posture (ibid.). Patients with body perception disturbances take longer to move the affected limb, because the expectancy of pain, and therefore also mental movement also becomes slower and in addition recognition of pictures of limbs from the same side as the affected become slow (Lotze & Moseley, 2007; Moseley, 2004b). In MVF the motor control system should be enhanced, in return also mental movement should be affected by MVF. Therefore hand laterality should provide a picture of the effectiveness of MVF with faster hand recognition after effective mirror therapy.

5.3.2 Questionnaire design

A questionnaire is developed to investigate different degrees of perceived ownership and sense of agency (Appendix 12.3 and 12.4). In the design of the questionnaire, it is considered desirable to use questions used in other experiments regarding MVF. This is to ensure the reliability and validity, but also to ensure the same understanding lies behind the concept of ownership (agency have not been investigated in the area of MVF), because this will make comparisons to other studies conclusions possible. The questions included will therefore be derived from other sources, when possible. The requirements, for the questions included, are that they should be closed-ended in order to keep the design quantitative, and make comparisons between conditions possible. Even though open-ended questions might be better to differences in subjective experiences, and do not enforce affected answers, they have to be coded and analyzed, which makes comparison more difficult (Brace, 2004). The design is build up on the comparison between conditions, so open ended questions seem inappropriate to use.

The questionnaire consists of 17 statements; eight of them concerning feelings of agency (Question 2, 4 , 5, 7, 9, 10, 14a and 14 b), seven concerning feelings of ownership (Question 1, 3, 6, 8a, 8b, 11 and 15) and two asking about, if the hands felt bigger during MVF (Question 12 and 13). There is an equal amount of positive and negative formulated statements to avoid response acquiescence bias, where participants are more likely to agree than disagree. Statements about ownership and agency, positive and negative formulated are mixed to further avoid acquiescence bias and pattern of answering (Brace, 2004; Coolican, 2004). Each statement should be rated on a seven point Likert scale ranging from 1 strongly disagree to 7 strongly agree. Seven points are chosen to ensure a greater discrimination than the typical 5 point scale offers (Brace, 2004). It is chosen only to name the extremities in order to avoid naming the middle point, which will be stated something like "neither agree nor disagree", because it is not wished to give the respondent the possibility of not taking a stance (ibid.). The questionnaire design was piloted in two experimental trials, where the participants were asked to elaborate their understanding of the questions, and if ambiguities occurred, the question was reformulated. In the control condition the words “mirror” and “mirror image” are removed, as the only change in the questionnaire.

The written statements are derived from several sources. Statements concerning ownership is partly derived from Longo et.al (2009) and Christoffersen & Petrini (in press). Agency statements are written on the basis of Christoffersen & Petrini (in press) and on the basis of Haggard & Tsakiris (2009) description of agency and the factors that constitute it. Agency should in Haggard & Tsakiris (2009) description include “*a person’s ability to control their actions, and through them, events in the external world*” (Haggard & Tsakiris, 2009, p. 242), and also includes the ability to predict the outcome of one´s actions (ibid.).

Ownership Statements

Longo, Betti, Agliotti & Haggard (2009): *It felt like I was looking directly at my hand rather than at a mirror image. It felt like the hand I was looking at was my hand. Did it seem like that hand you saw was a right or a left hand*.

Christoffersen & Petrini (in press): *It seemed that the hand in the image belonged to me. The left hand in the image was not my hand. Did you feel you were in control of the hand in the mirror* (including duration: *Did you feel you were in control of the hand in the mirror image all the time*).

One statement was self generated: *It felt like the hand I was looking at was somebody else´s* hand

Agency Statements

Christoffersen & Petrini (in press): *I felt as if I had no control of the hand in the image. It seemed like I could move my hands like I wanted to*.

Self-generated statements: *I did not feel, I was in control of the objects I moved around. I felt it was me, who produced the movements the hand in the image made. I did not feel the hand in the mirror moved as I expected it to do. The hand in the image moved as I expected it to do.*

Enlargement Statements

Christoffersen & Petrini (in press): *I had the feeling my left hand became larger. I had the feeling my right hand became larger.*

5.4 Design

As described in the introduction, the current study will be experiential, because it is wished to try to isolate variables, and establish the relationship between the types of tasks, ownership, agency and the effects of MVF.

The study is designed as a repeated measure design, which has the advantage of eliminating the influence of inter-subject variability on the results. The study includes six conditions testing for the influence from mirror type and task type; Neutral mirror - simple tasks, Neutral mirror - complex tasks, Enlarging mirror – simple tasks, Enlarging mirror – complex tasks, Without mirror – simple tasks, Without mirror – complex tasks (see figure 5 and 6. for overview). The conditions are given in a random order to avoid order effects. The randomization is done with help from http://www.randomizer.org/about.htm, which uses the “math.random” method to generate its numbers (Urbaniak, G. C. & Plous, S., 2007). Because the final number of participant were smaller than planned for, the randomization was not complete, and the conditions did not appear in the same order equal number of times, which potentially have influenced the results, so that they display order effects.

Another problem generated from the repeated measure design is, that the participants engage in six conditions. Therefore they might get bored or unable to focus during all tasks. There were plenty of breaks included in the experimental design to avoid the participants were getting tired, but it cannot be ruled out that it happened. It is not known for how long the effects of the mirror last. Therefore is it possible that the first mirror conditions have influenced the results in the last conditions.

5.5 Procedure

The experimenter starts out by introducing the participants to the study, before they given their informed consent. Afterwards the Hand Recognition test is completed as a baseline measure for the participants' laterality. Before assessment the participants are asked to remove any identifying items from their hands e.g. pieces of jewellery or watches. This is done to ensure the visible hand appears similar to the hidden hand. Then the participant finishes each condition followed by the Hand Recognition Test and the questionnaire. A small break is provided before moving on to the next condition. Before each condition the participants are asked if they are ready to continue, or if they need a longer break, this is done to ensure participants are able to concentrate during all conditions. See figure 5.

To make sure the participants stay focused during all conditions, the tasks are similar, but not exactly the same in each simple and complex condition. This can be seen in figure 6 which displays the specific tasks used in each condition.

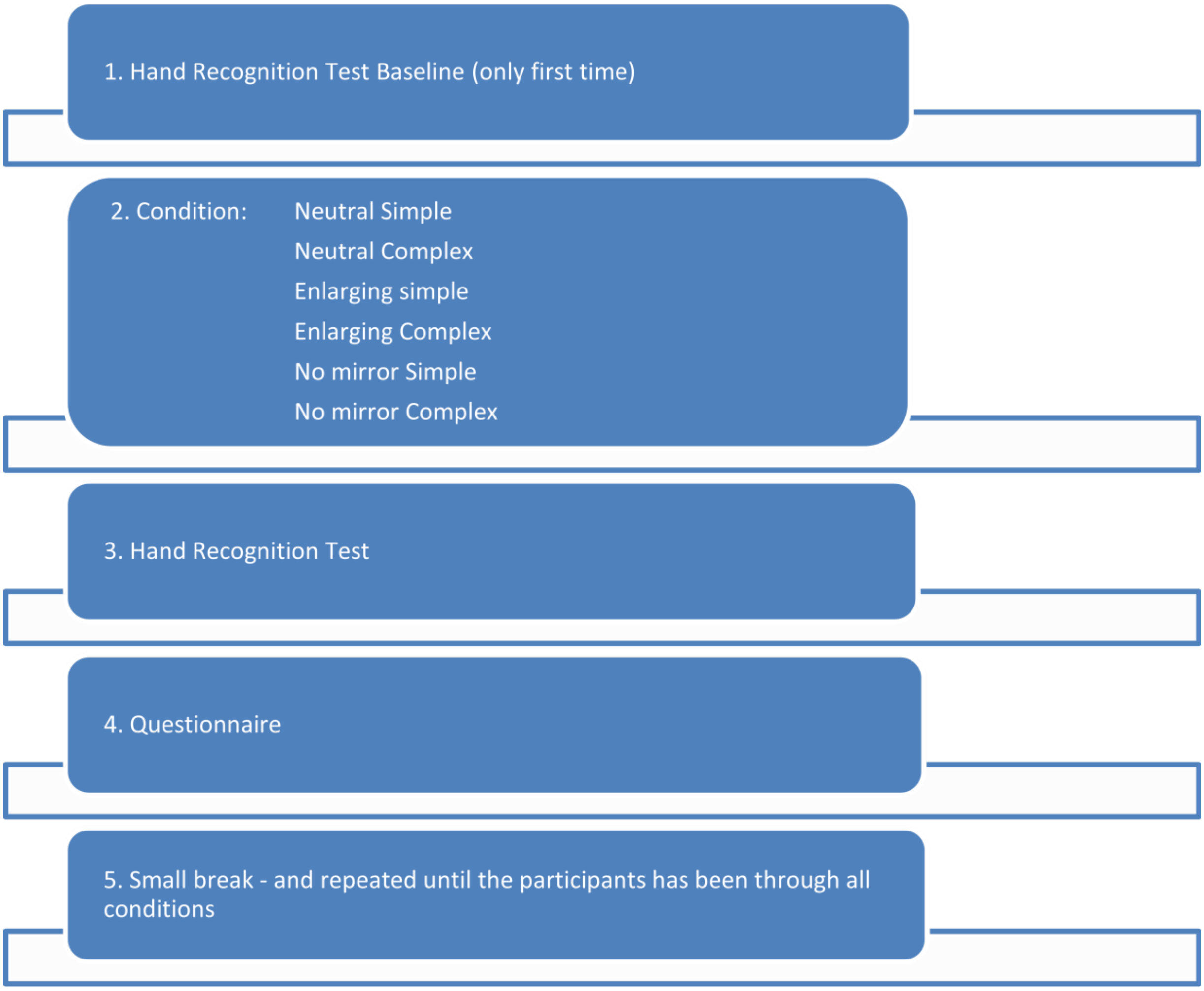

Figure 5: *the procedure steps.*

Procedure (step 2-4)

Neutral Mirror		Enlarging Mirror	
Simple (6 min)	Complex (6 min)	Simple (6 min)	Complex (6 min)
Pool A: Press a ball Touching finger to thumb Turn a cube Lifting hand up/down Spread and gather fingers	Pool A: Puzzle House Move small pearls Maze A1 B1C1	Pool B: Trundle a ball under the hand Lifting hand up/down Lifting hand with palm turn against mirror Finger tapping Move an object around	Pool B: Puzzle House Move large pearls Maze A2 B2 C2
Hand Recognizing (2 min)	Hand Recognizing (2 min)	Hand Recognizing (2 min)	Hand Recognizing (2 min)
Questionnaire (5 min)	Questionnaire (5 min)	Questionnaire (5 min)	Questionnaire (5 min)

Without Mirror	
Simple (6 min)	Complex (6 min)
Pool C: Move an object Turning hands Lifting hand with palm turned against mirror Trundle a ball under the hand Finger tapping	Pool C: Puzzle House Move Small and Large pearls Maze A3 B3 C3
Hand Recognizing (2 min)	Hand Recognizing (2 min)
Questionnaire (5 min)	Questionnaire (5 min)

Figure 6: *Step 2 to 4 in the procedure.*

5.6 Data analysis

Prior to date collection, the appropriate the statistical methods are decided on the basis of the level of measurement.

Data from the hand recognition test appears at interval level, which makes it suitable for parametric tests. A Likert scale is used in questionnaire answers, which formally produce data at ordinal level, but it has been argued, and empirically tested, that Likert scales produce "*empirically interval data*" (Carifio & Perla, 2008, p.1150). Also evidence support that F-tests used to analyse ordinal data produces unbiased results (ibid.). Therefore it has been chosen to treat data from the questionnaire concerning ownership and agency as interval level. This allows testing the questionnaire date with parametric tests, which is desirable, because they have greater statistical power than their non-parametric equivalents (Brace, Kemp & Snelgar, 2006).

Statistical analyses are performed using SPSS 18. Parametric tests are used with the critical value of $p \leq 0{,}05$ considered significant.

Repeated measure analysis of variance (ANOVA) are used to analyses most data, which allows investigating the effects of several independent variables at once. When significant differences are found between more than two factors, a Bonferroni post hoc test is applied, to determine which conditions differ significantly. If Mauchly´s test of Sphericity is significant ($p < 0{,}05$), the assumptions for a normal within-subjects ANOVA have been violated. If so the Greenhouse-Geisser Epsilon is used (Brace et al., 2006). Partial eta squared η^2, is used to estimate the effect size, and tells what proportion of the variance attributes to the factor. The suggestions by Cohen will be used to interpret the effect size, where 0.1 is considered a small effect, 0.25 is a medium effect and 0.4 is a large effect (Walker, I., 2007). Also independent t-test is used when determining if two means are significantly different from another and a Pearson´s correlation test to see the relationship between two variables.

Mirror and tasks: Analysis are done by using a Repeated Measure ANOVA design with three factors: 2 (hand RT) * 2 (task RT) * 3 (illusion RT) and 2 (hand AC) * 2 (task AC) * 3 (illusion AC).

Additional Questions: A mixed ANOVA test is used to test for *gender* differences, where gender is applied as a between-subjects variable. The participants are divided into two groups according to their baseline scoring, where the median value divides the two groups into a high RT baseline and a low RT baseline group. *Baseline scores* are tested to be predictive of the subsequent RT scores using an independent t-test with baseline scoring groups as between subject's variable.

Ownership and Agency: The questionnaires inter-reliability is tested at first with Cronbach´s alpha. As the rule of thumb predicts, it is tried to reach a Cronbach´s alpha of minimum 0,7 (Brace et al., 2006), but because the same questionnaire is used six times, it might be lower in one or two conditions. Analysis of variance between condition is done with a two-way repeated measure ANOVA, 3 (illusion) * 2 (task) for both ownership and agency. Data from the questionnaire is calculated into grouping variables for both ownership and agency. In order not to miss any effect caused by the small number of participants, the participants are divided into group (low ownership and high ownership; low agency and high agency) for each condition. The division is made between participants scoring over and under the median, and subjects who scored the exact value of the median were considered to be part of the "high" end groups. An independent t-test is done between groups within each condition in order to investigate, if ownership and agency ratings influence RT. At last a Pearson´s correlations test is used to investigate the relationship between ownership and agency ratings.

6.0 Results

6.1 Participants

23 subjects participated in the experiment, 12 males and 11 females - all participants fulfilled the experiment. All subjects were right handed. Mean age was M = 25,43 years ranging from 19-38 years, female M = 23 years, males M = 27,67 years. The difference between mean age for male and female are considered small enough for gender variability to be analyzed.

6.2 Accuracy

Accuracy scores (AC) reflect the percentage correct judged pictures. It is expected that no significant effects should occur for either illusion, tasks, or hands, but the results are included in the analysis to ensure the participants have not given random guess of hand recognition test.

The repeated measure ANOVA for AC scores (3 illusion * 2 task * 2 hand) shows that there are no significant main effects of illusion, $F(2,44) = 0,908$, $p = 0,411$, partial $\eta^2 = 0,040$, no significant main effect of tasks, $F(1,000;22,000) = 1,322$ Greenhouse-Geisser corrected, $p = 0,263$, partial $\eta^2 = 0,057$ and no main effects of hand, $F(1,000;22,000) = 0,194$ Greenhouse-Geisser corrected, $p = 0,664$, partial $\eta^2 = 0,009$. There are no significant interaction: between illusion and task, $F(1,22) = 0,648$ Greenhouse-Geisser corrected, $p = 0,528$, partial $\eta^2 = 0,029$, between illusion and hand, $F(2,44) = 0,501$, $p = 0,609$, partial $\eta^2 = 0,022$ or between task and hand, $F(1,000;22,000) = 0,198$ Greenhouse-Geisser corrected, $p = 0,661$, partial $\eta^2 = 0,009$. There are no significant interaction between type of mirror, task type and the hand recognized, $F(2,44) = 1,974$, $p = 0,151$, partial $\eta^2 = 0,082$. A post hoc pairwise comparison (Bonferroni) do not reveal any significant differences.

From the above analysis, it can be supported that the conditions do not influence the accuracy of hand recognition.

The values of 50% correct answers or below are thought to indicate the participants had been guessing, but as can be seen in table 1, the mean AC scores are above this level.

Condition		**N**	**Mean**	**Std. Deviation**
Baseline	left	23	79,04	11,741
	right	23	81,43	15,570
Neutral Simple	left	23	87,57	9,229
	right	23	84,78	13,142
Neutral Complex	left	23	88,17	8,563
	right	23	88,87	9,241
Enlarging Simple	left	23	87,78	7,988
	right	23	84,52	12,030
Enlarging Complex	left	23	88,30	11,174
	right	23	88,17	11,500
Without Simple	left	23	84,43	15,359
	right	23	87,48	10,582
Without Complex	left	23	85,87	12,469
	right	23	84,57	13,737

Table 1: *Mean and SD of left and right hand AC. There do not seem to be support for the participants answer randomly, since all AC scores are above 50%.*

To ensure RT does not depend on more or less accurate hand recognition, RT and AC scores are correlated. If there is a correlation with lower AC producing faster RT, then the results might reflect a trade off. Results from the paired sample t-test can be seen in appendix 12.5.1 There was a significant negative relationship between RT and AC in the *enlarging mirror simple tasks* condition for *left* hand (r = -0,408, N = 23, p = 0,053, two-tailed) and the *neutral mirror simple task* condition for *right* hand (r = -0,454, N = 23, p = 0,030, two-tailed), but in both conditions the linear trend in a scatter plot shows (Appendix 12.5.1a & 12.5.1b) that, when AC increases RT decreases. Therefore, the faster RT should not be caused by more random guessing.

6.3 Analysis of effects from mirror, task and hand

The following section will analyze if conditions influenced the hand laterality.

The repeated measure ANOVA with three factors; 3 (illusion) * 2 (task) * 2 (hand) showed the main effect of illusion are non-significant, $F(2,44) = 0,114$, $p = 0,893$, partial $\eta^2 = 0,005$. The main effects of task type are non-significant, $F(1,000;22,000) = 3,003$ Greenhouse-Geisser corrected, $p = 0,097$, partial $\eta^2 = 0,120$. The main effects of hand are significant $F(1,000;22,000) = 11,211$

Greenhouse-Geisser corrected, $p = 0{,}03$, partial $\eta^2 = 0{,}338$. The interaction of mirror, task and hand are non-significant, $F(2,44) = 0{,}112$, $p = 0{,}895$, partial $\eta^2 = 0{,}005$.

A post hoc pairwise comparison does not reveal any other significant effects.

As expected the participants are faster at left hand recognition compared to right hand recognition, but it is consistently in all conditions and not just the mirror conditions, which is not expected. The mean score and standard deviation (SD) of left and right hand RT can be seen in table 2 and figure 7.

Condition	Hand	N	Mean	Std. Deviation
Baseline	Left	23	1,813	0,4994
	Right	23	2,030	0,5676
Neutral Simple	Left	23	1,913	0,5755
	Right	23	2,074	0,5748
Neutral Complex	Left	23	1,809	0,5900
	Right	23	1,974	0,6225
Enlarging Simple	Left	23	1,904	0,5103
	Right	23	2,061	0,6287
Enlarging Complex	Left	23	1,822	0,5359
	Right	23	1,948	0,5672
Without Simple	Left	23	1,852	0,5791
	Right	23	1,978	0,6612
Without Complex	Left	23	1,839	0,5922
	Right	23	1,991	0,5510

Table 2: Mean and SD of left and right hand RT for each condition. In all conditions, the left hand recognition is faster than right hand RT.

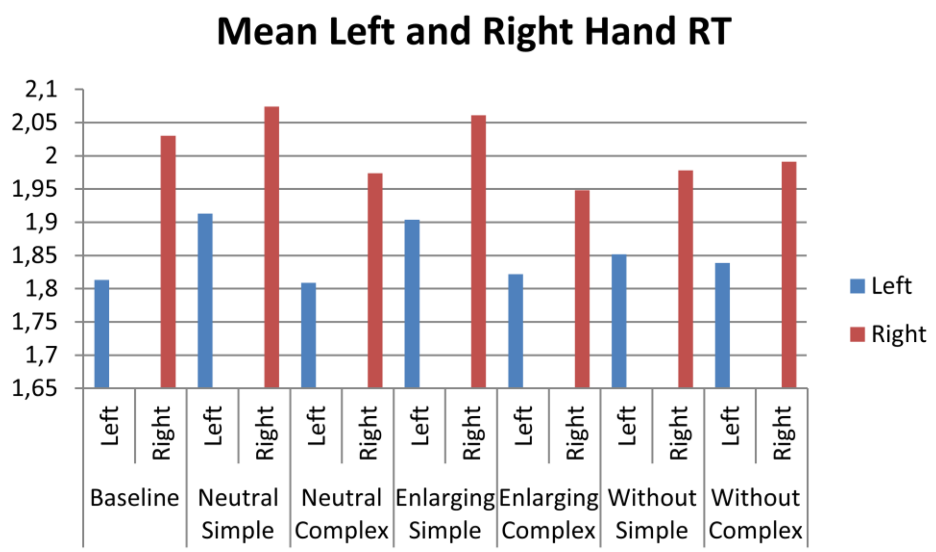

Figure 7: *The bar chart shows the mean RT for left and right hand recognition in the seven different conditions.*

The ANOVA test also reveals there is no significant difference between mirror conditions or task which indicates MVF has not had an impact in the current experiment. There is a tendency for faster left hand recognition after complex tasks during mirror conditions, which will be explored below.

6.4 Simple and complex tasks

It is expected that subjects are faster at left hand recognition after complex tasks compared to after simple tasks, and that they are faster after the mirror conditions compared to the without mirror conditions.

In the bar charts (figure 7 and 8) there seems to be a trend towards lower RT after complex tasks compared to simple tasks in the neutral and enlarging mirror conditions. This is investigated using a two-way repeated measure ANOVA for simple and complex tasks within each mirror condition; 2 (task) * 3 (illusion). The main effect of task type are not significant: $F(1{,}000;22{,}000) = 2{,}370$ Greenhouse-Geisser corrected, $p = 0{,}138$, partial $\eta^2 = 0{,}097$. The main effect of type of mirror are not significant: $F(2{,}44) = 0{,}030$, $p = 0{,}971$, partial $\eta^2 = 0{,}001$. There are a non-significant interaction between type of task and type of mirror: $F(1{,}573;34{,}614) = 0{,}473$ Greenhouse-Geisser corrected, $p = 0{,}581$, partial $\eta^2 = 0{,}021$. Applying Bonferroni post hoc pairwise comparison do not reveal any significant differences between conditions.

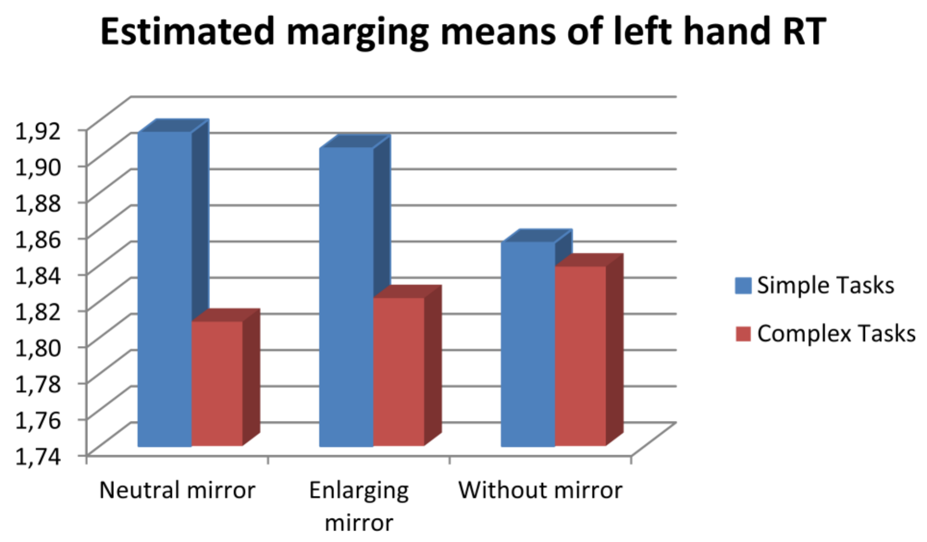

Figure 8: *Estimates of marging means between simple and complex tasks in the neutral, enlarging and without mirror conditions.*

As can be seen both neutral and enlarging mirrors show the same tendency for subjects to be faster at recognizing left hand images in the complex tasks conditions. Because of the difference to the no mirror condition, it is tried to see if any significant task effects appear, if the without mirror condition is left out.

A two way within subjects ANOVA is conducted. The factors are 2 (tasks)*2 (mirror). There are a significant effect of task type: $F(1,000;22,000) = 4,696$ Greenhouse-Geisser corrected, $p = 0,041$, partial $\eta^2 = 0,176$. There are a non-significant effect of mirror: $F(1,000;22,000) = 0,001$ Greenhouse-Geisser corrected, $p = 0,977$, partial $\eta^2 = 0,000$ and a non-significant effect of task*mirror: $F(1,000;22,000) = 0,042$, Greenhouse-Geisser corrected, $p = 0,839$, partial $\eta^2 = 0,002$.

Therefore, when the without condition are left out, there is seen a significant effect of task, which is in accordance with the expectancies.

6.4.1 Right hand picture recognition

It is investigated if recognition of right hand is also influenced by task type, but it is assumed it is not.

A two-way repeated measure ANOVA 3 (illusion) * 2 (task) design are conducted to see if any effects of tasks or mirror occurred in the current sample. The main effect for tasks is non-significant: $F(1,000;22,000) = 1,772$ Greenhouse-Geisser corrected, $p = 0,197$, partial $\eta^2 = 0,075$. The main effect for mirror type is non-significant: $F(2,44) = 0,213$, $p = 0,8fv09$, partial $\eta^2 = 0,010$.

The interaction of task and mirror are non-significant: $F(2,44) = 0,821$, $p = 0,447$, partial $\eta^2 = 0,036$.

Depictured in a histogram (figure 9) the estimated margin means looks like the following.

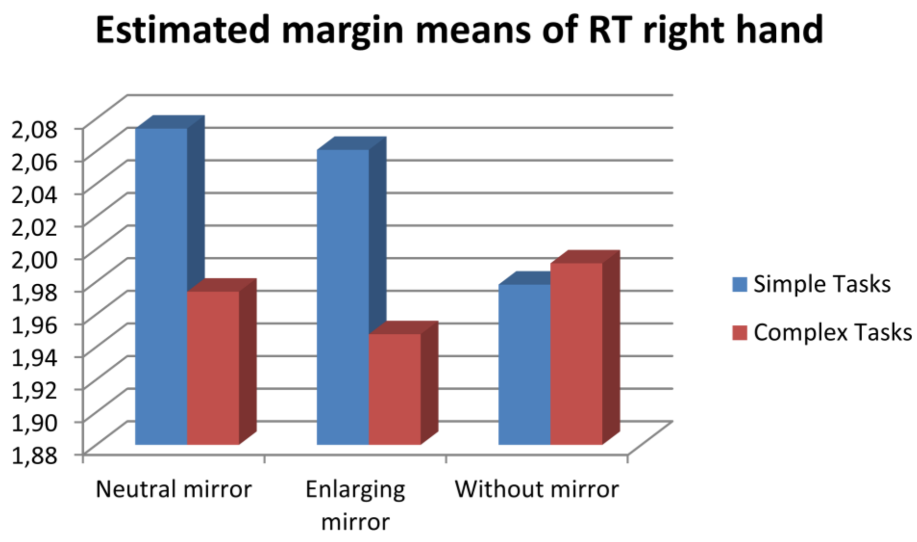

Figure 9: *Estimated margin of right hand RT means between simple and complex tasks in the mirror conditions.*

As for left hand the graphs show the condition without mirror stands out. Therefore the two-way within subjects ANOVA are tried on only the conditions with mirror. 2 (task) *2 (illusion). The main effect for tasks is, close to, but non-significant: $F(1,000;22,000) = 4,025$ Greenhouse-Geisser corrected, $p = 0,057$, partial $\eta^2 = 0,155$. The main effect of mirror is non-significant: $F(1,22) = 0,173$ Greenhouse-Geisser corrected, $p = 0,681$, partial $\eta^2 = 0,008$. The interaction between task and mirror are non-significant: $F(1,22) = 0,014$ Greenhouse-Geisser corrected, $p = 0,906$, partial $\eta^2 = 0,001$.

Influences of tasks on RT does almost reach a significant level, which implies that the task type influence the results in hand recognition test independent of the influence from the mirrors. The difference between simple and complex tasks are very small in the without mirror, and show opposite tendencies of faster RT after simple tasks. This implies, it is the effects of different tasks used under MVF that influence the RT.

6.5 Summary

It can be seen in table 2, the RT do not vary a lot between conditions.

Most clearly is a distinction between *left and right hand* recognition, where left hand recognition is faster than right hand recognition in all conditions (table 2, figure 7).

There are not seen any effects of *mirror* for left and right hand recognition, which suggests the MVF have not had an impact on the participants hand recognition. It was expected that there would be fastest RT after neutral and enlarging mirror conditions, and slower RT in the baseline measurement and the without mirror conditions. As can be seen in table 2, this is not the case. The *baseline measurement* of RT for left hand recognition is, besides one exception, lower than all other conditions. It was expected that the baseline measurement would be higher than all mirror conditions, and similar to without mirror conditions, because the MVF should result in an update of the motor control system (see section 2.2.6). In addition there is not seen a difference between left hand RT in *mirror conditions (neutral and enlarging)* and the *without mirror conditions*.

For *left* hand RT, there is not seen any significant variation between *tasks,* when all conditions are included. It is tried to do the analysis without the no-mirror condition, because the effects of complex tasks should only be obtained in mirror conditions, if the effects should be due to an interaction of MVF and complex tasks. The analysis (without the no-mirror condition) shows significant results of a task effect, with faster recognition after complex task, which supports hypothesis 1. As can be seen in figure 8, only in the *neutral mirror and the enlarging mirror conditions* there is a difference between simple and complex tasks with RT for left hand being faster after complex tasks. RT does only differ a little bit between simple and complex tasks, with the fastest RT after complex tasks, in the *without mirror condition*. These results are expected, because if differences should be due to task effects on MVF, there should be no difference between simple and complex tasks in the without mirror conditions.

For RT *right* hand, there are no significant effects of tasks, but when the without mirror conditions are removed from analysis, the level of significant effect of tasks are almost reached. The RT of right hand recognition was expected not to be influenced by the mirror illusions, and therefore to be higher than left hand recognition in the mirror conditions and similar to left hand RT in the baseline and without mirror conditions. Generally there is higher RT for right hand recognition compared to left hand in all conditions. The *baseline measurement* is higher than all conditions except from the neutral and enlarging mirror conditions with simple tasks. There does not seem to be a difference between mirror and without mirror conditions, in accordance with the expectations.

Accuracy scores do not correlate significantly with RT scores in most condition, which supports that there is no trade of effect between AC and RT. No significant effects of illusion, task or hand are seen for AC scores. As can be seen in table 1, AC scores is lowest in the *baseline measurment* for both left and right hand. For left hand, there is lower scores of AC in the *without mirror condition*, and almost equal scores in the four mirror conditions.

6.6 Enlarging mirror effects

The impact from the enlarging mirror is also assessed in the questionnaire, where two questions are included: *I had the feeling my left hand became larger. I had the feeling my right hand became larger.*

When repeated measure ANOVA, 3 (illusion) * 2 (task) analysis are conducted for the feeling that left hand is experienced to be enlarged, there is seen a significant effect of illusion $F(1,436;30,623) = 21,623$ Greenhouse-Geisser corrected, $p < 0,001$, partial $\eta^2 = 0,507$, a non-significant effect of task $F(1,000;21,000) = 0,069$ Greenhouse-Geisser corrected, $p = 0,795$, partial $\eta^2 = 0,003$ and a significant interaction of illusion and task $F(2,42) = 4,102$, $p < 0,024$, partial $\eta^2 = ,163$.

A post hoc pairwise comparison between illusion conditions reveals only the neutral and enlarging mirror conditions differs significantly from each other (estimated margin of means = 1,886, $p < 0,001$ Bonferroni corrected). Differences to without mirror condition are non-significant (estimated margin means = 0,682, $p = 0,072$).

Repeated measure ANOVA 3 (illusion) * 2 (task) are also applied to the question about the feeling that the right hand feels enlarged. There is a close to, but non-significant effect of illusion, $F(1,578;34,707) = 3,323$ Greenhouse-Geisser corrected, $p = 0,058$, partial $\eta^2 = 0,131$. There is a significant effect of task, $F(1,000;22,000) = 6,336$ Greenhouse-Geisser corrected, $p = 0,020$, partial $\eta^2 = 0,224$. There are a non-significant interaction of illusion and task, $F(1,338;29,431) = 2,567$ Greenhouse-Geisser corrected, $p = 0,088$, partial $\eta^2 = 0,105$. A post hoc pairwise comparison shows a non-significant difference between neutral and enlarging conditions (estimated margin means = 0,022, $p = 1,000$ Bonferroni corrected) and between neutral and without conditions (estimated margin means = 0,500, $p = 0,162$ Bonferroni corrected), but there are a significant difference between enlarging and without conditions (estimated margin means = 0,478, $P = 0,014$ Bonferroni corrected).

The above results indicate the enlarging mirror has influenced the perceived hand size for both left and right hand. Figure 10 shows the differences in the experienced enlargement between conditions.

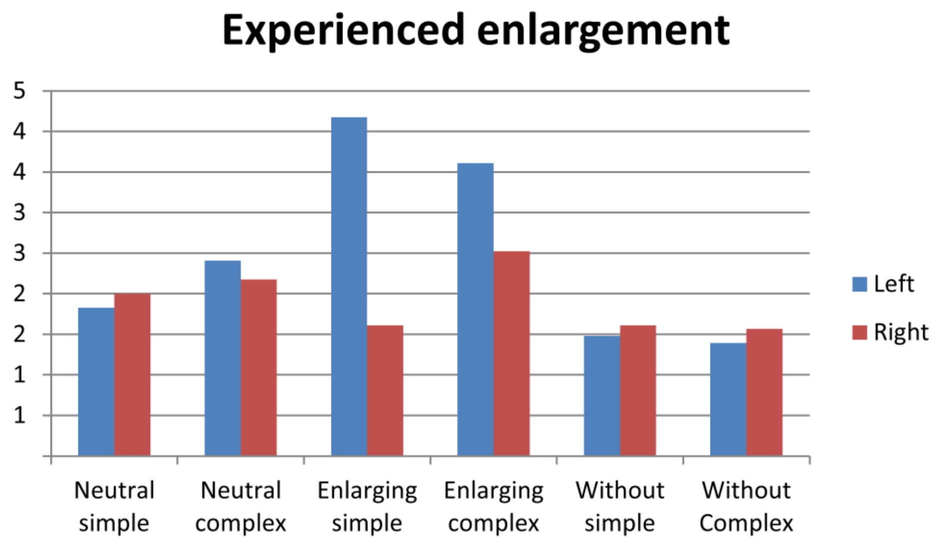

Figure 10: *The experienced enlargement of left and right hand. In the enlarging mirror conditions, left hands are rated to be felt more enlarged than right hand.*

6.7 Response time according to Gender

It is investigated, if there is a difference between men and women´s RT using a mixed ANOVA design 3 (illusion) * 2 (hand) * 2 (task) with gender as the grouping variable. Gender mirror interaction is non-significant, $F(1,815) = 0,119$ Greenhouse-Geisser corrected, $p = 0,877$, partial $\eta^2 = 0,006$. Gender task interaction is non-significant, $F(1,21) = 0,678$, $p = 0,419$, partial $\eta^2 = 0,031$. Gender hand interaction is non-significant, $F(1,21) = 1,562$, $p = 0,225$, partial $\eta^2 = 0,069$. Gender, mirror illusion and task interaction is non-significant, $F(1,913) = 0,89$ Greenhouse-Geisser corrected, $p = 0,418$, partial $\eta^2 = 0,041$. The gender, illusion and hand interaction is non-significant, $F(1,824) = 0,21$ Greenhouse-Geisser corrected, $p = 0,811$, partial $\eta^2 = 0,10$. The gender, task and hand interaction is non-significant, $F(1,21) = 0,11$, $p = 0,916$, partial $\eta^2 = 0,001$. The overall interaction of gender, illusion, task and hand are non-significant, $F(1,737) = 2,544$ Greenhouse-Geisser corrected, $p = 0,099$, partial $\eta^2 = 0,108$.

There are seen no significant effects of gender, therefore this will not be discussed further.

6.8 Baseline

It is investigated, if the baseline measurement of the RT in the hand recognition task can be predictive of the RT scores in subsequent conditions. The analysis is conducted as an independent t-test with *baseline scoring groups* as grouping variable. The baseline scoring groups are defined according to the median baseline RT (median = 1,800), where the first group contains all participants who scores the median value or more, and the second group contains all participants who scores below the median. The high baseline measurement group contains 12 participants, and the low baseline measurement group contains 11 participants. See table 3.

Condition	Group	Mean	Estimated mean difference	Sig. (2.-tailed)
Neutral Simple	low baseline group	1,582	0,635	0,005
	high baseline group	2,217		
Neutral Complex	low baseline group	1,464	0,661	0,004
	high baseline group	2,125		
Enlarging Simple	low baseline group	1,645	0,496	0,016
	high baseline group	2,142		
Enlarging Complex	low baseline group	1,536	0,547	0,011
	high baseline group	2,083		
Without Simple	low baseline group	1,527	0,623	0,007
	high baseline group	2,150		
Without Complex	low baseline group	1,573	0,511	0,035
	high baseline group	2,083		

Tabel 3: *The table displays the mean for high and low baseline measurement groups RT left hand, their estimated mean difference and the significant value for their variation*

The baseline score is predictive for the RT in so that participant scoring high RT on the baseline measurement also score higher RT´s on all other conditions compared to participants scoring low RT in the baseline condition, they also score lower RT in all other conditions. Table 3 shows the mean RT left hand recognition for each group. The mean differences were significant between all groups.

These results indicate that the participant keep the same ability to hand laterality throughout the current study.

6.9 Questionnaire

6.9.1 Inter Reliability

The same questionnaire is used in all six conditions to measure feelings of ownership and agency, with the only difference being "mirror" and "mirror reflection" is left out in the questionnaire for the control conditions. It is expected that there will be differences between subjects ratings of ownership and agency in the different conditions, therefore the inter reliability is tested in each condition.

The following table 4 shows inter reliability for ownership and agency in each condition.

Ownership

Condition	Cronbach´s Alpha	Cronbach's Alpha Based on Standardized Items	Number of items	Mean
Neutral Simple	0,750	0,807	7	6,071
Neutral Complex	0,802	0,811	7	5,045
Enlarging Simple	0,830	0,838	7	5,526
Enlarging Complex	0,842	0,850	7	4,975
Without Simple	0,399	0,534	7	6,605
Without Complex	0,852	0,928	7	6,617

Agency

Condition	Cronbach´s Alpha	Cronbach's Alpha Based on standardized Items	Number of items	Mean
Neutral Simple	0,762	0,801	7	5,783
Neutral Complex	0,850	0,858	7	4,071
Enlarging Simple	0,854	0,868	7	5,280
Enlarging Complex	0,820	0,821	7	3,919
Without Simple	0,666	0,766	7	6,410
Without Complex	0,651	0,671	7	5,909

Table 4: *Reliability of questionnaire. Item 4 is removed from the measurement of agency.*

Item 4 was removed from the measurement of agency, because there generally are observed a better reliability when this item is removed.

6.10 Ownership

The mean ownership is displayed in the following bar chart, figure 11.

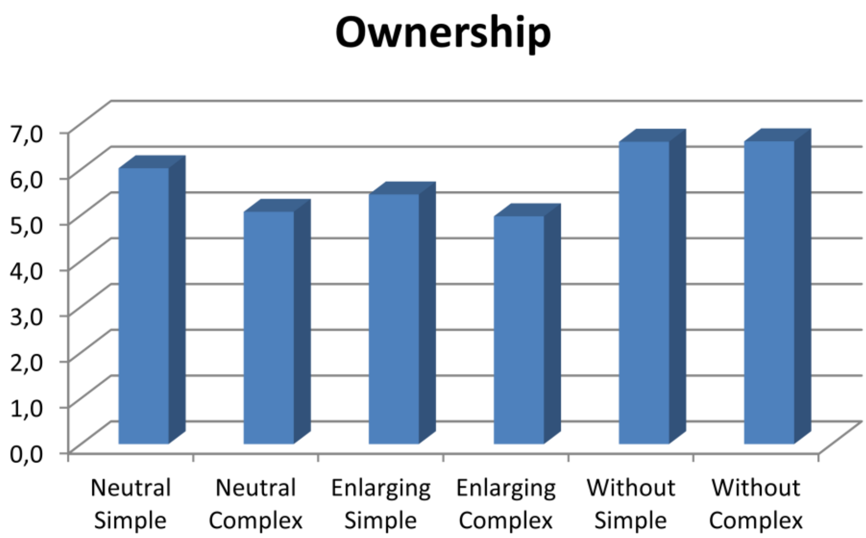

Figure 11: *The bar chart shows the mean values for ownership. It can be seen that the means for ownership are almost the same in the neutral and enlarging condition, but looks a bit higher in the conditions without mirror.*

To see if there are any significant difference between ownership ratings in the six conditions a repeated measure ANOVA with factors 3 (illusion) * 2 (tasks) is used. The results show a significant difference of ownership between mirror conditions, $F(2,44) = 35,33$, $p < 0,001$, partial $\eta^2 = 0,616$. There is a significant effect of task, $F(1,000;22,000) = 13,013$ Greenhouse-Geisser corrected, $p = 0,002$, partial $\eta^2 = 0,372$. The interaction of task and illusion are significant, $F(2,44) = 5,882$, $p = 0,006$, partial η^2 = = 0,211.

A post hoc test pairwise comparison shows that only no-mirror and mirror illusion conditions are significantly different from each other (estimated margin means = 1,059, $p < 0,001$ Bonferroni corrected). Between neutral mirror and enlarging mirror the effects are non-significant (estimated mean difference = 0,335, $p = 0,164$, Bonferroni corrected).

It is wanted to investigate if the degree of experienced ownership has an impact on the effectiveness of MVF, which here is defined as laterality to hand recognition. The expectance is that higher degree of experienced ownership will lead to faster recognition of left hand pictures.

This is investigated with a Pearson's correlation. No significant correlations are found between ownership ratings and RT (Appendix 12.5.2).

Because of the relative small number of participants in the study, it will be hard to find any differences between participants, who score high on ownership compared to those how score low on ownership. In order not to miss any effect caused by the small number of participants, the participants are divided into two groups: low ownership and high ownership for each condition. The division is made between participants scoring over and under the median, and subjects who score the exact value of the median are considered to score high on ownership. No participants score high or low in every condition; therefore the participants are divided into different groups in each condition (table 5).

	Median	N participants high	N participants low
Neutral Simple	6	13	10
Neutral Complex	5	14	9
Enlarging Simple	5,71	12	11
Enlarging Complex	5	14	9
Without Simple	6,71	13	10
Without Complex	7	13	10

Table 5: *Median values that separate the ownership ratings into two groups; high contains all participants who rated ownership the same or above the median value, low contains all who rated below the median. Number of participants in the groups is showed in the second and third columns.*

An independent t-test is done with each condition with left hand response times. None reach the level of significance. The results are listed in appendix 12.5.4.

6.11 Agency

The mean agency scores are depictured in the following bar chart, figure 12.

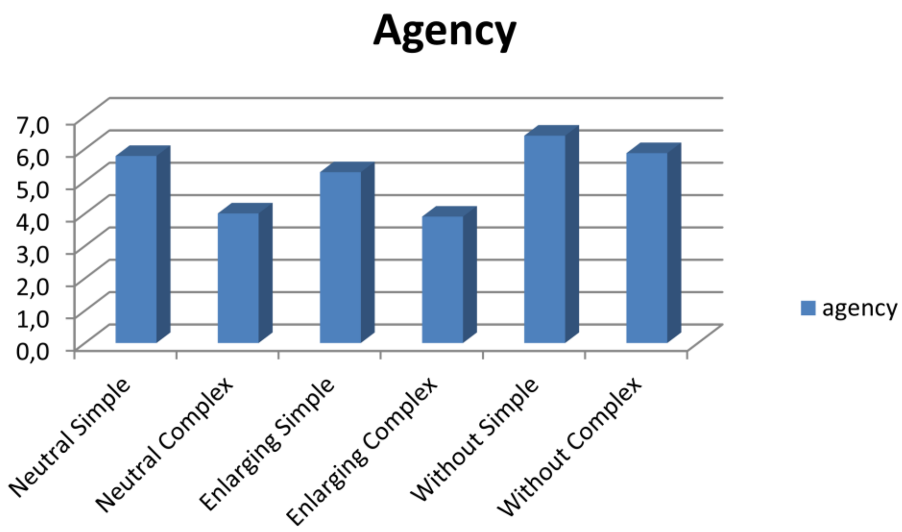

Figure 12: *The bar chart shows the mean values for agency. There seems to be a small tendency, that agency means are lower after complex tasks.*

To see if there are any significant difference between agency ratings in the six conditions a repeated measure ANOVA are used with factors 3 (illusion) * 2 (task). There are a significant difference in the agency ratings between mirror conditions, $F(2,44) = 52{,}372$, $p < 0{,}001$, partial $\eta^2 = 0{,}704$. There is a significant effect of task, $F(1{,}000;22{,}000) = 95{,}124$ Greenhouse-Geisser corrected, $p < 0{,}001$, partial $\eta^2 = 0{,}812$. There is a significant interaction of task and illusion on agency ratings, $F(1{,}507;33{,}161) = 8{,}554$ Greenhouse-Geisser corrected, $p = 0{,}002$, partial $\eta^2 = 0{,}280$. A post-hoc test reveals that there is not a significant difference between neutral and enlarging mirror conditions (estimated mean difference = 0,301, $p = 0{,}229$, Bonferroni corrected), but only between mirror and without mirror conditions (estimated margin means = 1,245, $p < 0{,}001$, Bonferroni corrected).

It is investigate if the degree of experienced agency has an impact on the effectiveness of MVF effectiveness using a Pearson's correlation. No significant correlations are found between agency ratings and RT (Appendix 12.5.3).

As for ownership the participants are divided into two groups: high and low agency, to be better able to detect any relationship between feelings of agency and MVF effects measured as RT. The participants are divided according to the median value where participants scoring the same or above the median value are considered to be part of the high agency groups, and participants scoring below are part of the low agency group. The division is made into different groups in each condition because the participants do not score consistently high or low across all condition.

	median	N participants high	N participants low
Neutral Simple	5,71	12	11
Neutral Complex	4,14	13	10
Enlarging Simple	5,57	12	11
Enlarging Complex	4,14	13	10
Without Simple	6,57	14	9
Without Complex	6	13	10

Table 6: *The median value for agency ratings in the six conditions, and the number of participants in each group. The high group contains all participants scoring the value of the median or above, the low group contains all participants scoring below the median.*

An independent t-test investigating agency groups´ influence on RT with each condition shows a few significant results (Appendix 12.5.5). In both simple enlarging condition and complex without mirror, there is seen a significant effect of agency on RT. In the enlarging mirror simple task condition, there is a significant effect that participants have faster RT left hand, when reporting high agency (mean 1,73) compared to low agency (mean 2,09). The difference between conditions are -0,36 and at the 95% confidence interval for the estimated population mean difference is between -0,78 and 0,07. An independent t-test shows, that the difference between conditions is significant ($t = -1{,}756$, $df = 21$, $p = 0{,}047$, one-tailed). In the without mirror complex task condition, the high agency group (mean 1,65) is faster at recognition of left hand images compared to the low agency group (2,08). The mean difference between conditions is 0,42 and at the 95% confidence interval of the estimated population mean difference is between -0,92 and 0,07. An independent t-test shows that the difference between conditions is significant ($t = 1{,}795$, $df = 21$, $p = 0{,}044$, one-tailed).

6.12 Correlation between ownership and agency

A paired sample correlation is done to see if ownership and agency ratings correlate.

Agency correlation with ownership: Paired Sample Correlation				
Condition		**N**	**Correlation**	**Significance**
Neutral Simple	Mean Ownership vs RT	23	0,380	0,074
Neutral Complex	Mean Ownership vs RT	23	0,544	0,007
Enlarging Simple	Mean Ownership vs RT	23	0,523	0,011
Enlarging Complex	Mean Ownership vs RT	23	0,562	0,005
Without Simple	Mean Ownership vs RT	23	0,641	0,001
Without Complex	Mean Ownership vs RT	23	0,378	0,075

Table 7: *The correlation of ownership and agency ratings*

As can be seen in table 7, there is a positive correlation between ownership and agency ratings in all conditions – except the neutral mirror simple tasks and without mirror complex tasks. In these two conditions, there is almost reached a significant relationship.

6.13 Summary

There are seen a significant higher rating of ownership after simple tasks in the neutral and enlarging mirror conditions, but no significant difference of ownership ratings in the no-mirror condition. There do not seem to be a relationship between ownership ratings and RT neither using a Pearson's correlation nor with dividing the participants into a high or low ownership group and making independent t-tests.

There is a significant difference between participant´s ratings of agency after simple and complex tasks in all mirror conditions, with higher ratings of agency after simple tasks. When the participant´s are divided into a high and a low agency rating group, there is a significant relationship between group and RT left hand in the enlarging simple and the no-mirror complex conditions with higher ratings of agency correlating with faster RT.

7.0 Discussion

The last part of the thesis will discuss the results in relation to other experimental findings. The discussion will be divided into sections, which discuss the findings concerning the hypotheses one at a time. At first the effects of the mirrors will be discussed, followed by a discussion, of findings concerning tasks. The last sections will deal with the impact ownership and agency has on the MVF effectiveness.

7.1 Mirror effects

In this section, results concerning the effects of the mirror versus without mirror conditions will be discussed. The relationship between left and right hand recognition is included in the discussion. Afterwards the effects of the enlarging mirror will be analyzed separately, followed by a discussion of the impact of using healthy participants instead of patients with pain conditions and/or motor function impairments.

Two mirror- and one no-mirror condition are included in the current experiment. RT to recognize left hand pictures are used to express differences between conditions. It is expected that RT will be faster in the mirror conditions, because the visual feedback provided by the mirror, activates neural circuits underlying motor execution. Therefore MVF should prime the motor system, which should result in faster mental execution of movements (McCabe, 2010; Moseley, 2004b; Stevens & Stoykov, 2003).

There are not seen a significant difference between mirror and no-mirror conditions in the current experiment, which means the mirrors might not have had an impact on the participants motor control system, or at least that the hand recognition task do not measure such an impact.

This result will be discussed in relation to differences between left and right hand recognition in the following section.

7.1.1 Left versus right hand response time

If the MVF do not work, there should be no difference between left and right hand recognition, because MVF should only increase activation in the hemisphere ipsilateral to the mirror (right) hand, thereby improving motor performance and mental motor performance of the hidden non-mirror (left) hand. By looking into the results concerning right and left hand recognition, this becomes ambiguous, because there is a significant effect of faster left hand recognition compared to right hand recognition, but the effects are consistent in all conditions, including the baseline measurement. If the difference should be ascribed to the effects of the mirrors, then there should not be a difference between left and right hand RT in the baseline and without mirror conditions.

The fact that left hand[5] RT is faster in all condition is surprising, and cannot be explained as an effect of faster recognition of the non-dominant hand. This is because previous work on the hand recognition test have found an equal RT to right and left hand recognition (Hudson, 2005; Moseley, 2004b), or that hand recognition is fastest for the dominant hand (Nico et al., 2004). In the original investigations (Parsons, 1987b) of left and right hand judgment, it was found that laterality depended on the awkwardness of the position, and not on which hand was dominant or non-dominant. This means that the result, showing left hand recognition to be faster in the baseline measurement and during all condition, is highly unlikely to be due to a general tendency to faster recognition of the non-dominant hand.

One explanation for the results might be that the hand recognition test used in the current experiment favours left hand recognition. The test is developed by the NOIGroup (http://recognise.noigroup.com/recognise), and the rules and instructions for the images included in the tests are not well described. It might be, that the left hand images are not placed in as awkward positions as the right pictures. Another possibility is that the introduction given to the participants primes them to pay more attention on their left hand. If a subject pays more attention to one hand than the other, this can reflect itself as faster RT for that hand, e.g. in the first few weeks of CRPS the patients pay more attention to the affected hand, which results in faster RT for that hand (Butler, 2009). Prior to the experiment, participant was asked if they were right handed, and the mirror was already placed with the reflection side to the right. It seems highly unlikely but cannot be ruled out that this limited information have directed attention towards the left hand.

In sum, the results do not support that the mirror conditions are different from the no-mirror conditions. This might be because the mirrors do not have an impact on the participants. The result that left hand recognition is faster than right hand recognition, point towards left hand recognition is affected in the current experiment, but the explanations for this might relate to the hand recognition test used favours left hand recognition, or the participants become primed to focus on left hand. It is also likely that the effects of the mirror do not translate into changes in the motor control system of healthy participants. This will be discussed in section 7.1.3.

[5] Non-dominant hand since all participant were self-evaluated to be right hand dominant

In the following section, the results concerning the enlarging effect from the mirror illusion will be discussed in order to look for support for the mirror illusion did occur in the participants.

7.1.2 Enlarging mirror

There can be found some support for the mirror illusion to occur, in the results concerning the enlarging mirror. In the current experiment an enlarging mirror are included in order to see if the magnification of the mirror reflection has an impact on the effectiveness of MVF. The enlarging mirror does not seem to affect RT to left hand recognition, but the body image might be affected.

To see if the body image is influenced by the enlarging mirror, the participants are asked to rate if their right or left hand felt enlarged in the mirror conditions. There is a significant effect, that the left, non-mirrored hand is perceived as being enlarged in the enlarging mirror condition. The left hand should only be perceived as being enlarged if the mirror illusion cheats the brain into incorporating the mirror reflection into the body image. This can be seen as support for the mirror illusion occurred, because it influenced the body image of the participants.

Previous studies investigating the effects of manipulation of hand size with minifying or enlarging mirrors have found an impact on both acute and chronic pain as described in section 4.1.2 (Mancini et al., 2010; Moseley et al., 2008; Ramachandran et al., 2009). In chronic pain, a minifying mirror is thought to modulate the pain by changing the perceived size of the painful limb to be smaller, which also leads to the pain being perceived less. The painful limb is often felt enlarged in chronic pain therefore the minifying mirror might help establish a corrected body image. It is possible that the enlarging mirror only influence the body image, and not the body schema[6], which in the current study means that the effects is not reflected in changes in the motor system. If this is true, then no effects from MVF would be reflected in the hand recognition test. These statements open a greater discussion of the differences between body image and body schema, but it is a very wide-ranging debate, which I will not be able to go into detail with in the current thesis.

The results from the questionnaire supports that the enlarging mirror has created an illusion of the one limb being magnified which suggests the mirrors have been effective in some way.

7.1.3 No influence of the motor control system of healthy subjects?

In the following section, I will discuss, why there are not seen any effects from MVF on the RT results. The discussions will not centre on the potential limitations in the hand recognition test.

[6] In the discussion, I will use the concepts of body image and body schema as defined by de Vignemont in section 1.4.3: definitions. The terms will be used in regard to the definitions and not depending on how the different authors have used them, because the concepts are often used interchangeable.

Instead the possibilities that MVF do not translate into changes in the motor control system in healthy subjects will be explored.

As outlined in the theory section 2.2.6, the most accepted theory for the mechanisms behind MVFs effect is that MVF creates a coherent body image by matching motor intentions with sensory feedback. This should in return prime the motor control system, in so that the efference copies are updated. Although it has been criticised that the studies investigating MVFs effect only have poor to moderate quality of evidence, many studies see changes in the motor control system; e.g., as progressed motor rehabilitation (Altschuler et al., 1999; Dohle et al., 2009; Rosen & Lundborg, 2005; Stevens & Stoykov, 2003; Sütbeyaz et al., 2007; Yavuzer et al., 2008) or as regained voluntary control of a phantom (Brodie, Whyte & Waller, 2003; Brodie et al., 2007; Giraux & Sirigu, 2003; Mercier & Sirigu, 2009; Ramachandran et al., 1995). Because of many studies suggesting MVF influences the motor control system, it was expected that MVF would also influence the motor performance in healthy subjects.

The experimental design should not be responsible for a missing effect, since most of the guidelines concerning MVFs application have been followed. See section 3.2 for the guidelines and section 5.3 for the procedure in the current design. Therefore other explanations are investigated.

One explanation could be that there is a difference between healthy subjects and patients with neurological conditions responses to MVF. The predictions about the results in the current study are primarily derived from literature investigating the effectiveness of MVF in patients with cortical reorganizations or brain damages. Conclusions from a study using healthy subjects should only carefully be transferred to groups of patients and opposite (Michielsen et al., 2011). Therefore it is likely, that MVF do not affect the motor system in healthy subjects.

It has been suggested that MVF has a stronger impact on healthy subjects, because changes might not be as easily achieved in a damaged hemisphere, because the damage has induced changes in neural activity (Michielsen et al., 2011, p.394). The opposite has also been suggested. Altschuler (2005) state that effects from MVF may be stronger in subjects with neurological lesions, than in healthy subjects because "*such subjects may not have all sensory modalities intact to alert the brain to an illusion*" (p. 1154). This suggests influences from MVF do not express itself as much in healthy subjects, because the sensory feedback system warns the brain of the illusion. Results regarding feelings of ownership do not support this statement. In the current experiment, there are high ratings of ownership in all mirror condition. Previous researchers have used ownership-ratings as a measure for the illusions effectiveness, where high ratings of ownership of the mirror reflection are perceived to reflect a successful MVF (Longo et al., 2009; Mancini et al., 2011). I do not wish to use ownership as a measure for the effectiveness of MVF, because this has not been experimental investigated, but the results regarding ownership do tell the mirror cheated the participants in the current experiment into thinking the mirror image belong to their real body. Therefore, the explanations for the missing relationship between MVF and RT might be that either MVF do not improve the motor system in healthy individuals, or the hand recognition test does not measure the influence from MVF.

Other studies have shown an influence from MVF on healthy subjects. Evidence is found for an analgesic effect provided by MVF to healthy participants (Longo et al., 2009) and Garry, Loftus & Summer (2005) found unilateral movements during MVF to increase ipsilateral M1 excitability in healthy subjects. This suggests that MVFs effect can translate into motor system changes in healthy participants. But these changes might not be evident in hand laterality. Despite MVF induce an increased M1 excitability; the effects may not express itself as faster hand recognition. The reason MVF should result in faster hand recognition is (as described in section 2.2.6 and 5.3.1) that the false but corrective visual feedback updates the motor control system. In healthy subjects, the motor control system should hopefully be fully updated, because they have no disturbances of the bodily perceptions to create mismatches between motor intentions and sensory feedback processes. Therefore the results in the current study might reflect that since the mirror only provide the same visual information as direct vision of the left hand would, no corrections are done to the motor control system, and no changes will be visible in motor performance. No improvements of laterality abilities will therefore be seen. Following this argumentation, the current study provides a slight support for the mechanisms behind MVF to be the mismatch theory.

The effects of MVF have also been suggested to be caused by an activation of mirror neurons. The mirror neurons should be activated through the observation of the movements in the mirror reflection, which in return should enhance motor evoked potential in the hidden hand. These effects may express itself more clearly if the motor performance is inhibited, but because no effects are seen of enhanced laterality, it might also suggest that the activation of mirror neurons hence enhancement of motor evoked potentials are not the mechanism behind MVF effects.

Even if the effects of MVF are able to improve the motor control system of healthy subjects, the intervention used in the current experiment might not be long enough to really make a difference. The experiments investigating the effectiveness of MVF to post-stroke patients have had the patients to use the mirror for at least four to six weeks (Altschuler et al., 1999; Eng et al., 2007; Sathian, Greenspan & Wolf, 2000; Steven & Stoykov, 2003; Yavuzer et al, 2008). The effects of the mirror illusion can show itself immediately, as when it provides an analgesic effect (Longo et al., 2009) or when different symptoms is reported after just 20 seconds of exposure to a mismatch created by moving the limbs incongruently in front of the mirror (McCabe, 2005), which are the reason, it was expected, that the mirror effects could be measured with HR test, if conducted straight after the mirror intervention. It would be interesting to apply MVF to healthy subjects for a longer period of time, to see if any motor performance changes would then occur.

In sum, there are found no evidence for a significant effect of the mirrors in the current experiment, because RT to left hand recognition do not differ significantly. It is seen that the enlarging mirror affects the perceived size of the non-mirrored hidden hand, which indicates there has been some kind of mirror effect. Other explanation to the missing difference between experimental conditions might be that the hand recognition test used in the current experiment favour left hand recognition or the participants are primed to pay more attention toward the left hand. Another possibility is that MVF do not influence the motor control system in healthy subjects, but this seems less likely since other studies have found MVF to affect health subjects. More likely MVF influences healthy subjects, but the effects are not seen in the hand recognition test, because the motor system is well functioning in healthy participants, and in order to be able to see any changes, the MVF should be used for a longer period of time.

If the findings are related to the proposed mechanisms underlying the effect of MVF, then there do not seem to be any support that MVF has distracted the participants from their hidden hand, since this might have induced an enhanced RT to left hand recognition. Rather the participants pay more attention to the left hand, because the left hand RT is decreased. If the underlying mechanism is to correct a mismatch, then the current study tells there need to be a mismatch to be reduced, for MVF to have an impact on the motor control system.

7.2 Tasks

In the following section the results concerning simple and complex tasks will be discussed in relation to other studies success to incorporate tasks of greater complexity. There have not been found any studies which compare the effects of simple/physiotherapeutic movements with complex/goal-directed task, therefore the discussion regarding the effects of complex tasks will take its stance from studies using goal directed movements. In the end of the section, the incorporation of complex tasks into clinical practice will be discussed.

In accordance with the first hypothesis, there is seen a significant effect of faster left hand recognition after complex tasks, but the result could only be obtained when the no-mirror conditions are left out. Therefore the participants differ significantly on RT between simple and complex tasks in the four mirror conditions, but not in the without mirror condition. Therefore the results support that only in mirror conditions tasks will influence the hand laterality, whereas bimanual movements in the no-mirror condition should not influence the hand laterality.

In order for the results of simple and complex tasks to be related to the mirror effects, there should only be seen a significant effect of tasks for *left* hand recognition in the mirror conditions. But for *right* hand recognition there is almost seen a significant faster RT after complex tasks, when the no-mirror conditions is left out of analysis. Because the effects of faster RT after complex tasks are not exclusively for left hand, the results should be interpreted cautiously, and the results may not be attributed as an effect of MVF. It is important to note, that left and right hand recognition should not depend on each other. Therefore, if left hand recognition becomes faster, right hand recognition is not necessarily faster as well. That is because when determining which side a body part belongs to, the subjects starts out by guessing (normally the guess is always correct), which side it could be, and thereafter the hand is mentally moved to the given posture (Parsons, 2001). Therefore the faster right hand recognition after complex tasks should not be a consequence of the faster left hand recognition.

The effect sizes are in both the left and right hand analysis considered small due to Cohen´s interpretation of effect size. The partial eta squared tells what proportion of the variance in the dependent variable is attributable to the factor (Walker, 2007), which means that when the effect size is small the variance might be ascribed to influence from other variables. For example, the differences between simple and complex tasks conditions could be due to differences in increased attention towards the limbs, i.e., the demands from the complex tasks might induce a forced attention towards the hands, which as described in section 7.1.1 may result in faster RT.

The results from the without mirror conditions support that the effects of faster RT after complex tasks is a combined effect of task and mirror, because there is not seen a difference between simple and complex tasks in the without mirror conditions. This suggests that the effects of complex tasks relates to the mirror illusion, because if the difference had been due to enhanced attention during complex tasks, then the effects of complex tasks should also be visible in the without mirror conditions. In the without mirror conditions, only left hand is visible during the tasks whereas there are `two´ hands, real and reflected hand, visible in the mirror conditions. The difference between mirror and without mirror conditions might be due to this difference of one versus two hands visible. In order to be able to conclude that the effects of complex tasks relates to the mirror illusion, a control condition, where both hands are visible during the tasks, would need to be done, in order to make sure the effects are not related to the viewing of one or two hands.

In sum, results related to the difference in RT after simple and complex tasks, show tendencies for complex tasks to enhance the effects of MVF, or at least it can be supported that complex tasks conducted with two visible hands reduce RT for both left and right recognition.

It can be questioned if it really matters if complex tasks enhance hand laterality with or without MVF. The theory behind hand recognition claims a direct relationship between hand recognition, mental movement performance and execution of movements (Parsons, 2001) (See section 5.3.1). Improvement of hand laterality should in return improve mental - and real motor performance, which is the aim of the treatment. In the graded motor imagery program formulated by Moseley (2004a; 2006), hand recognition is used before MVF, because it is thought that the hand laterality ability is necessary for MVF to work (Butler, 2009). Therefore, if complex tasks influence hand laterality in a positive direction, with or without MVF, it should lead to improved motor functioning.

Previous studies have also found support for complex tasks to improve motor functioning in VR MVF (see section 3.3). It has been suggested that complex goal-directed tasks might be superior to traditional MVF intervention because a fewer interventions might be needed during VR MVF. In addition, the goal-directed tasks seemed to enhanced concentration and motivation to engage in the treatment (Eng et al., 2007). Therefore, complex tasks seem to carry potential to improve MVFs effect in rehabilitation of motor functioning. The theoretical assumption about using complex task are that is should cause a greater activation of motor related areas in cortex. This is also suggested by Sato et al. (2010), who believe that in their VR MVF treatment the activation in motor-related areas of cortex is stronger compared to traditional mirror box treatment, because the goal oriented tasks forces patients to plan the movement of reaching out and grasping virtual objects. This planning causes greater activation of motor related areas. The reduced RT during complex task in the current experiment is thought to relate to such an increased activation.

Complex tasks might also improve the analgesic effect of MVF, but as Michielsen et al. (2011) suggest, the effects might depend on different mechanisms than in motor performance rehabilitation. In the theory section 2.2.6 describing the mechanisms by which MVF seems to work, it is suggested that MVF might have an effect, because it distracts the patient from the painful limb. The complex tasks might improve this effect, because it is necessary to pay more attention towards the task in order to be able to accomplish it. Enhanced focus on the tasks might distract the patient from the affected limb, which is also suggested by Murray et al. (2007). They found VR MVF with goal-directed tasks to have an analgesic effect in three patients suffering from PLP, and ascribed part of the effect to the tasks, which distracted the patient from the painful limb. Therefore, the underlying mechanism for the effects of MVF to pain and motor rehabilitation might be different.

Complex tasks as part of MVF have also been suggested to enhance concentration and motivation to engage in treatment and make the patients feel rewarded during treatment (Sato et al., 2010). Due to the verbal expression during the current experiment, the participants were more committed to the complex tasks. In a few cases, it was expressed that the simple tasks became dull. Therefore the potentials of complex tasks may not be limited to an improved cortical activation, but also to enhanced motivation and concentration.

In sum, there can be found support for the hypothesis that MVF conducted with complex task improves motor functioning. The effects are only being seen in the mirror conditions for left hand RT, and close to, but not exactly significant for right hand RT. The results are ambiguous; the influence from complex tasks on right hand recognition points towards the effect is independent from MVF, but because either left nor right hand recognition are influenced in the without mirror condition, the effects might relate to MVF. Even if it is not the mirror that causes the enhanced hand laterality, there seems to be potential in including complex tasks, because the motor system might be primed and the tasks seems to be motivating and rewarding. It has not yet been established if the effects of complex tasks also apply to MVFs analgesic effect, but complex tasks might enhance the effects of MVF by distracting the patient from the painful limb, and through that improve movement in the affected limb.

7.2.1 Practical implementation

As the above summary states, there seems to be great potential in complex tasks, but the tasks may be difficult to do in complete congruence and especially when using a normal mirror. This will be discussed in the following section.

Studies, supporting MVF is well conducted with complex tasks, are with one exception conducted through VR. It might be more difficult to do complex tasks with a normal mirror. The mirror box operates in a very narrow dimension and demands that the patients sit in a relative fixed position to avoid seeing the affected hand behind the mirror (Murray et al., 2007, p.1465f). Therefore complex tasks as part of MVF might be limited to VR since some of the fundamentals in MVF might be violated, when trying to do more complex tasks in front of a normal mirror. This is also seen in the current experiment, where the participant moved incongruently because they could not find the object on the non-reflective side. Also the participant seemed to make bigger movements with the hidden hand, which often made them touch the back of the mirror. This illustrates some of the problems associated with implementation of complex tasks to MVF, and the problems might be even more pronounced in patient with movement difficulties.

The assumption that movements should be done in complete congruence is not shared by all MVF therapists (e.g. Butler, 2009), and might not be that much of an obstacle in implementing complex tasks. Michielsen et al. (2011) investigated the cortical activation in post-stroke patients moving the hands bimanual or unimanual. Only bimanual movements during MVF increased cortical activity, different from without mirror conditions, but the increased activity was seen in the precuneus and posterior cingulated cortex which are areas associated with self-awareness and spatial attention. Therefore it is suggested that *“it is not so much the illusion of a virtual moving hand that causes this activation, but the mismatch between the movement one performs and the movement that is observed”* (Michielsen et al., 2011, p. 396). This suggests that even though the movements were “only” performed as well as possible, and not necessary in complete congruence, MVF have a positive impact on the rehabilitation process.

It might be difficult to develop complex tasks, there can be adjusted to patients with limited motor performance abilities. Using VR systems to provide the visual feedback will make the job much easier because simple movements can be implemented as part of virtual games. But virtual reality systems are expensive, not as accessible as a normal mirror (Ramachandran & Altschuler, 2009), and since the MVF are advised to be used every day in several weeks, it is convenient to do MVF at home.

In sum, it is not unproblematic to include complex tasks in MVF treatment. There is a risk that the effect of MVF is diminished if the tasks are done incongruently. Opposite does evidence suggests it do not matter if movements are done incongruently, as long as both hands are moved. There might also be a problematic aspect of conducting complex tasks with a normal mirror, because it works in a narrow dimension. Maybe complex tasks are best conducted with virtual reality systems.

In the following section, the influence of ownership and agency will be described, followed by a short coupling to the discussions of illusion and task effects.

7.3 Ownership

Feelings of ownership of the mirror reflection are described to be important for the mirror illusion to work (Eng et al, 2007; McCabe, 2010; Mercier & Sirigu, 2007). This has not been empirically investigated using MVF, but in an rubber hand experiment Ehrsson et al. (2005) found subjective ratings of ownership to correspond to activation of brain areas there are related to an efficient rubber hand illusion (Ehrsson et al., 2004). Since the effects of ownership have not been investigated in MVF, it seems critical to draw conclusions to MVF treatment. The rubber hand illusion occurs because visual information dominates touch and proprioceptive information, which leads to the illusion that the rubber hand belongs to the person's body. It is the same effect that is wished to be achieved in MVF; just it is the reflection of the non-affected hand, which is tried to be incorporated into a patient's body image.

In the current experiment, it is expected that ownership ratings will influence the effects of MVF. The results from the current experiment do not seem to support this, because there is seen no correlation between ratings of ownership and RT for left hand. Even if divide into groups due to participant scoring high or low ownership rating, no relationship is found between ownership and RT.

Different things can account for this missing relationship. First of all, it is very likely the missing relationship between ownership ratings and RT is caused by the missing ability to achieve any significant effects of the mirror (as discussed in section 7.1). Despite this, there is seen a significant effect of tasks, and ownership ratings do not correlate with that either. Part of this missing relationship might be due to limitations in ownership measurement, or because the experimental setting influenced ownership ratings more that RTs.

In the current study, there is seen a significant difference in ownership ratings between mirror and without mirror conditions, and between simple and complex task conditions. The highest ratings of ownership are in the control condition, where the participants are asked if they felt ownership of their real right hand. These ratings are, as expected, significantly higher than ratings of ownership in the neutral and enlarging mirror conditions. There is also a significant effect that the participant felt more ownership after simple tasks compared to complex tasks (see below for elaboration). This significant variability between conditions suggests the questionnaire is able to detect difference in subjective experienced ownership during MVF.

The significant difference in ownership ratings might reflect that the participants had trouble moving in complete congruence during the complex conditions, and that they often touched different objects behind the mirror as described in the section 7.2.1. As described in the theory section 3.2, it is considered to be important to move the hands in complete congruence and to apply stimuli synchronised. Another explanation could be that the complex tasks activates the frontal lobes which controls efferent information and therefore more processing takes place during complex tasks. This increased processing might reduce the experience of the illusion. Seen in the light of the above discussion of the limitations in the current experiment to influence laterality, the results are influenced by too many other variables, to be interpreted as evidence for a missing relationship between ownership ratings and the effectiveness of MVF.

The results questions the notions by Mercier & Sirigu (2009) who proposed that differences in MVF outcome might be due to differences in susceptibility to believe in the mirror illusion. In the current experiments, there is no participant who scores high or low on perceived ownership in all conditions or at least in all simple or complex conditions. Therefore, it is not supported that participants are more or less susceptible to believe in the mirror illusion. This also questions if a missing ability to benefit from MVF, should be due to a missing ability to believe in the mirror illusion, as McCabe (2010) stated. Since the current study only included 23 participants, it is possible that all subjects participating are susceptible to believe in the mirror illusion. This is also seen because even in the low ownership groups there are perceived ownership of the mirror reflection (ratings are above four, which is the middle point on the Likert scale). Only in the neutral mirror complex tasks and enlarging mirror complex tasks conditions are the groups with low perceived ownership close to the middle, indicating an "*I do not know*" response. Therefore it is mainly effects of high and medium ratings of perceived ownership which is investigated to influence RT, and maybe if participants with low (1-3 on the Likert scale used) perceived ownership is compared to the medium and high group, there will be an effect of ownership on the MVF effectiveness. Therefore, the effect of low ratings of ownership on the effectiveness of MVF has not been measured.

Even though it is not possible draw firm conclusions about the relationship between ownership and the effectiveness of MVF, it needs to be pointed out that there actually might be a tendency for a negative relationship. There is a significant faster RT after complex tasks compared to simple; opposite there is a significant higher rating of ownership after simple tasks compared to complex. As the above discussions outline, many things can explain and might have influenced the results, but a small possibility is that ownership may not be important in MVFs effectiveness in motor rehabilitation.

It has been suggested, that MVF works differently in pain treatment and motor performance rehabilitation (Ezendam et al., 2009; Michielsen et al., 2011, p.393). If this is true, then ownership ratings might not influence the effectiveness to both pain relief and rehabilitation.

The mechanisms behind MVFs effects that are agreed upon by most are the correction of a mismatch between motor intentions and sensory feedback. The reorganizations in cortex cause a mismatch between motor commands and the sensory information, because cortical maps are changed and no longer portray the actual locations of body parts. The predicted outcome of act given action might therefore be different than expected. This can both results in a warning signal which is perceived as pain (Giraux & Sirigu, 2003, p. 109; McCabe, 2010, p. 3; McCabe & Blake, 2007, p. 106), and/or the mismatch will result in a problematic update of the efferent copies, which again leads to a disrupted motor performance. This is two very different outcomes from the same mechanism. Therefore it does not seem unlikely, that MVF works differently to pain treatment and motor rehabilitation. It might be that the main mechanism of MVFs effect in pain treatment is to create a coherent body image, whereas the main mechanism in motor performance rehabilitation is to update the efferent copies. In the current experiment, the high ratings of ownership and manipulation of the limb size using the enlarging mirror supports that the mirror reflection is incorporated into the body image. This is not reflected in the motor control system, measured as hand laterality. Therefore, there might be seen a small evidence for the mechanisms in MVF to be different to pain and motor rehabilitation.

In sum, because of insecurity about the effects from the mirror it is not possible to support that ownership is important for the mirror illusion to work; neither to support that it do not affect the illusion. Most likely the MVF intervention is not applied enough times for a difference in RT to hand recognition to be evident. There are seen differences in ownership in the current experiment, but not a systematic difference with some participants reporting a general lower or higher degree of ownership than others. This implies that there is no such thing as susceptibility to believe in the mirror illusion. The results are problematic to draw conclusions from, but still open a discussion of the possibility that MVF works differently in motor rehabilitation and pain treatment, and that ownership might not be important for both parts.

7.4 Agency

The influence of agency on the effectiveness of MVF has not been given much attention. Due to Gallese & Sinigalia´s (2010) description of ownership being dependent on action, the possibility opens that agency influence the effectiveness of MVF.

In the current experiment, there is a significant difference in feelings of agency between mirror and without mirror conditions, with the highest ratings of agency in the without mirror conditions. This result is expected, since the participants should feel more in control of their movements while looking directly at their real hand.

There is significant higher rating of agency after simple tasks compared to complex tasks. This probably reflects that the complex tasks are difficult to complete, and especially that the participants often touched, or grab hold of a different object with the hidden left hand. This causes incongruence between the movements of the hidden hand and the visual movements from the mirror reflection, which might be felt like missing control of the mirror image.

An interesting result in the current experiment is that agency ratings correlated with RT in two conditions. As for ownership ratings, the participants are divided into two groups representing high and low ratings of agency. In the enlarging mirror simple tasks and without mirror complex tasks conditions, the group means correlate with the RTs. In both condition, the high agency group scores lower RT than the low agency group. This is in line with the expectations, that high ratings of agency would improve the effects of MVF, but the results are only seen in these two conditions. In the rest of the conditions, there are not seen any significant effects of agency group on RT. The tendency for high agency groups to score lower RTs do not go for the rest of the conditions; in neutral mirror simple task and the without mirror simple task the opposite, low agency scoring lower RTs are seen. This makes an interpretation of the results very difficult. It is possible that under certain conditions (e.g. the combination of the perceived enlarged limb combined with simple tasks), the experienced sense of agency influences the effectiveness of MVF. Because the sense of agency is measured after the hand recognition test is done, it is possible, that the agency ratings, reflects how well it went in the hand recognition test, e.g. when the participants have felt they “were in control of the hand recognition test”, it might translate to more positive responses of feelings of agency afterwards in the questionnaire. Generally, it is not possible to make any firm conclusions on the basis of the current results.

In order to see, if ownership and agency ratings are related, as proposed by Gallese & Sinigalia (2010), the mean ratings of agency are correlated with the mean ratings of ownership. In all condition, except the neutral mirror simple tasks and without mirror complex tasks, the ratings correlated. In the two exceptions, the conditions almost correlated significantly. This suggests a strong relationship between feelings of ownership and the sense of agency. It does not seem surprising, because if you fell you are able to control the hand in the mirror image, then more likely you would fell it belongs to you.

In sum; the subjective reported feelings of agency are different between conditions with the highest ratings in the without mirror condition and after simple tasks. In two conditions, enlarging mirror simple tasks and without mirror complex tasks, ratings of agency correlated positive with RT to left hand recognition. But because there are seen tendencies for negative relationships between agency and RT, it is not possible to interpret the result as a relationship between the sense of agency and MVF effectiveness in general. Agency ratings correlated with ownership ratings, which suggests agency and ownership might reflect the same incorporation of the mirror reflection into the body image.

7.5 Methodological limitations

As the above discussions outline, there are several limitations in the design of the study. This next section will provide short descriptions of the limitations, in order to make sure the necessary precautions are taken in regard to the conclusions, and in order to be able to set up an improved experimental design.

One of server limitations in the current design is that the use of healthy participants makes it difficult to draw conclusions from the current study to groups of patients, and to actually state if the intervention used would also affect groups of patients. In relation to this is that the current study only investigated a relative small group of subjects. This makes it difficult to achieve significant effects, because if only a few subjects deviate from the general performance on hand laterality, no significant effects will be seen. This also causes an uncertainty that the significant effects achieved in the study do not express tendencies in the general population. This is also suggested by the low effect size obtained.

As discussed in section 7.1.3, the intervention with MVF in the current study is most likely not used enough times to influence the motor control system, measured as hand laterality. In addition, it might also be difficult to improve the motor control system of healthy subjects; therefore hand laterality is not a very reliant instrument to use to measure MVF effects.

Another problem in the current design may be, that there are included too many conditions. The later conditions might be influenced by the earlier conditions. Even though, the effects of this should be cancelled due to the randomization of the conditions, the results might still be influenced by it, and reflect the missing ability to achieve significant differences.

The current experiment therefore seem to suffer from several limitations, and to be able to draw any firm conclusions on the effects of tasks with different complexity and the effects of ownership feelings on MVF outcome, the experimental design needs adjustments.

8.0 Conclusion

The first motivation to write about MVF developed from an insight into the potentials of using MVF to treat pain conditions, which earlier had seemed very difficult to treat. Also the fascination of how an visual illusion is created, where a mirror reflection becomes perceived as being part of one's body inspired to further investigation of MVF. The visual illusion creates possibility to access body part which otherwise is not accessible - as a phantom limb. At the same time, critical writers urge caution to MVF, because many aspects of the treatment are not well investigated. E.g. the evidence regarding the effectiveness of MVF is still limited, and many studies are criticised for not have an appropriate level methodological value. The mechanisms by which MVF should work are not clarified, and the clinical application is not agreed upon.

The current study set out to investigate how to improve treatment with MVF, partly by trying to contribute to investigations which could be used to write clinical protocols of how to apply MVF. Two main areas became the focus of investigation; tasks used in MVF, and the how much impact feelings ownership of the mirror illusion has.

A suggestion by Mercier & Sirigu (2009), that the effects of MVF are determined by the ability to increase activation of cortical motor areas, combined with knowledge, that increased complexity of a tasks causes a more widespread activation of motor related areas (Roland, 2003), inspired to investigate how tasks of different complexity, influence the effects of MVF. MVF is among other things thought to work by reversing maladaptive reorganisations, and through that to restore motor performance, by creating a coherent body image and update internal models of motor control. Because several areas are involved in motor control, it is hypothesised that if more areas are activated during MVF then the treatment effects might be enhanced.

In addition it is investigated how feelings of ownership influence the MVF effectiveness. Ownership is by many considered to be an important part for MVF to work (Longo et al., 2009; Mancini et al., 2011; McCabe, 2010). This is probably derived from the RHI paradigm, where ownership is showed to be important for the rubber hand illusion to occur, but it has, as far as I am concerned, not been investigated if it really is important to feel ownership of the mirror reflection for MVF to have an effect. It was expected that ownership would prove to be important, because of the assumption that part of MVFs effect is to create congruence between motor intentions and false sensory feedback from the mirror reflection. But, it is assumed that, for the mirror reflection to provide sensory feedback it needs to be incorporated into the body image.

An experimental design is chosen as the appropriate method of investigation, because it gives opportunity to isolate and investigate the effects from a few variables; tasks and ownership feelings. In addition, only healthy subjects are recruited to participate, primarily because of ethical considerations and in order to exclude that differences in patient symptoms account for difference in the results. Hand laterality is chosen as measurement of MVF effects, because recognition of a limb involves the same neural structures as mental an actual execution of movements, therefore changes in laterality should reflect changes in the motor control system.

The results from the current experiment show, there is not a significant effect of mirror illusion on RT. This makes all other results problematic, because the MVF might not have influenced the participants. Explanations for this results covers limitations in the measurement of MVFs effect, the intervention are applied to briefly to change laterality, or it is difficult to improve the motor control system of healthy subjects because there is nothing to be corrected.

The hand recognition test in the current experiment shows left hand recognition is fastest in all conditions including the baseline measurement. Previous research of laterality cannot explain these results, since left and right hand recognition should not differ or favour dominant hand recognition, which would be right hand in the current experiment. The faster left hand recognition might therefore either be due to participants become primed to be more aware of their left hands in the introduction of the experiment, or the hand recognition test favours left hand recognition.

It is highly likely that the MVF intervention is done in too short a period of time to show any changes in the motor control system. In MVF to motor rehabilitation, an effect from MVF is most often evaluated a couple of weeks (variation in studies are approximately 4-12 weeks). In addition, it might be even more difficult to cause improvements in healthy participants´ laterality, because their motor control system is already updated.

The results concerning task type support the hypothesis that complex tasks improve the effectiveness of MVF. After complex tasks the RT is significantly lower than after simple tasks, but the effects might not exclusively be caused in relation to the visual feedback. The results become critical to interpret, since the mirror illusion might not have worked, and because the faster RT also applies to right hand recognition, which should not be influenced by MVF. The change in RT might therefore be caused, by a forced attention toward the hands during complex tasks. Previous research have proved that increased attention towards a hand reduce RT to recognize pictures of hands from that side. Despite these conditions, complex tasks might still improve the effect of MVF, because due to the close relationship between laterality and motor performance, enhancement of laterality should reflect enhancement of the motor control system. The findings from the current experiment regarding complex tasks do suggest a positive effect in motor performance rehabilitation, but do not tell if complex tasks also will improve the analgesic effects of MVF. It can be argued that the positive side effect in form of enhanced motivation and concentration, when using complex tasks, might also benefit patients in pain. Also the suggestion that complex tasks increase the effect of distracting the patient from the painful limb, which is proposed to be a possible mechanism for MVFs effectiveness, supports complex tasks can be relevant to implement in MVF to pain treatment.

The practical aspects of implementing complex tasks to MVF need to be considered. The experience in the current experiment is that it is very difficult to keep moving in complete congruence doing complex tasks. Especially if some kind of object manipulation is demanded. Therefore the potential of complex tasks might best be conducted when the visual feedback is provided in VR environments.

In the current experiment, no evidence are seen in regard to a positive relationship between ownership ratings and MVFs effects. High ratings of ownership do not correlate with faster RT. Actually minor tendencies for the opposite effect is seen, because the ratings of ownership is significantly lower in the mirror complex tasks conditions, which are the conditions with fastest left hand RT. The effect is nonetheless non-significant. A possible explanation for the tendency for a negative relationship might be that during complex tasks the participant moved incongruently causing reduced ownership.

The data do not support, ownership is a necessary precondition for MVF to work, since there is reported an experience of ownership in all conditions, but MVF does not seem to work. It cannot be ruled out that ownership is insignificant to MVF effects, but it is very likely limitation in the design account for the missing relationship.

The results do not support the notion by Mercier & Sirigu (2009) that some individuals might be more susceptible to believe in the mirror illusion, since all participants fluctuated differently between conditions. But the fluctuation is only between medium and high ratings of ownership, which leaves the possibility, that all participants were susceptible to the mirror illusion in the current experiment.

The investigation of ownerships influence on MVF effectiveness leads to propose a hypothesis that ownership might only play an important part to MVFs analgesic effects. It has been suggested that different mechanisms are responsible for the treatment effect in pain states and motor rehabilitation, and therefore it does not seem unlikely that ownership might be more important to achieve an analgesic effect. The reason for this should be that feelings of ownership are important to create a coherent body image, which might be the main mechanism in pain treatment with MVF. To confirm this many studies needs to be done, and the mechanisms underlying the effectiveness of MVF needs to be clarified.

The reported sense of agency differs significantly among conditions with highest ratings of ownership in the without mirror conditions, and the simple task conditions. This is thought to reflect that during complex tasks, incongruent movements reduce the feelings of control of the mirror reflection, since the visual feedback might contradict the expected motor output.

The expectance of higher ratings of agency to increase the effectiveness of MVF is seen in the enlarging mirror simple tasks and the no-mirror complex tasks conditions. The results are not well supported since negative relations between agency and RTs are seen in other conditions – but not significant. This makes it impossible to make any firm conclusions on the basis of the current results, but it might be that under certain conditions the effectiveness of MVF is influenced by the sense of agency.

The influence from agency is included, because ownership and agency according to Gallese & Sinigalia, section 3.5, is related and depend on each other. Therefore, the experienced sense of control of the mirror reflection might influence MVF effectiveness in the same way as ownership feelings. The reported experience of agency feelings correlated with the reported ownership feelings. This suggests agency might be equally important to the mirror illusion as ownership (all though the relationship is not firmly supported in MVF).

The current study set out to investigate how to improve MVF treatment by investigating, which influence tasks of different complexity have on the effects of MVF, and if perceived ownership is necessary to achieve an effect from MVF. Because mirror conditions do not differ significantly from the controlling, no-mirror conditions, it is difficult to draw on how to improve MVF. However there is a significant tendency for complex tasks to improve laterality, although it is possible, the influence is independent from a mirror effects. But since complex tasks also seems to carry other positive side effects as e.g. improving motivation to engage in treatment, complex tasks carries the potential of improving MVF treatment. Opposite, there are seen no evidence for a relationship between ownership ratings and MVF effects, therefore nothing in the current experiment supports that ownership is a necessary for MVF to be efficient.

Because the results in the current study is affected by sever methodological limitations, it seems relevant to explore how the design can be adjusted in order to measure the relationship between MVF effectiveness and tasks of different complexity, and feelings of ownership. This will be done as the final part of the thesis.

9.0 Perspectives

After discussing and presenting the main conclusions of the current experiment, there seems to be many limitations in the current design which causes problems to state conclusions on the effects of complex tasks and ownership feeling on MVF. Therefore it seems appropriate to finish the thesis with a few perspectives on, how the current design could be improved.

The main improvements in the current study will be to; include more participants, use the MVF intervention for a longer period of time and/or use another measurement for MVF effectiveness.

Including more participants might make it easier to determine significant effects. If only a few participants deviate a little from the general population in their performance on hand recognition or their ratings of ownership in the current study, it will affect the result so no significant trends are recorded.

Including more participants will still not change, that the intervention might have been applied to briefly to make any visible changes to the motor control system. Therefore, an improved design should also use MVF for a longer period of time, e.g. three weeks or more as is often used in studies investigation treatments effects from MVF (section 3.2).

Another measurement for the effectiveness of MVF will improve the design, because there is too much insecurity about the hand recognition test used. Brain imaging, e.g. EEG or fMRI, can provide an enhanced knowledge of the differences in cortical activation during simple and complex tasks with both mirror and without mirror conditions. This seems appropriate to do, since the tasks are defined in accordance to their ability to activate cortical areas. Another thing that will improve the design is to include groups of patients. Then traditional measures as validated pain scales, e.g. VAS, or motor performance measurements, e.g. Brunnstrom stage can be used. Thereby the results will also provide better comparison to previous research on MVF effectiveness. The inclusion of patients can with advantage be integrated with the use of brain imaging; thereby it might be able to detect changes in brain activation during complex and simple tasks, and in addition investigate the underlying mechanisms for MVFs effects.

10.0 References

- Acerra, N. E. & Moseley, G. L. (2005). Dysynchiria: Watching the mirror image of the unaffected limb elicits pain on the affected side. *Neurology* 65 (pp. 751-753)
- Altschuler, E.L. & Hu, J. (2008). Mirror therapy in a patient with a fractured wrist and no active wrist extension. *Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery* 42 (pp.110-111)
- Altschuler, E. L. & Ramachandran, V. S. (2007). Last but not least. *Perception* 36 (pp. 632-634)
- Altshuler, E. L., Wisdom, S. B., Stone, L., Foster, C., Galasko, D., Llewellyn, M. E. & Ramachandran, V. S. (1999). Rehabilitation of hemiparesis after stroke with a mirror. *The Lancet* 353 (pp. 2035-2036)
- Apkarian, V. A., Bushnell, M. C., Treede, R. & Zubieta, J. (2005). Human brain mechanisms for pain of pain perception and regulation in health and disease. *European Journal of Pain* 9 (pp. 463-484)
- Berlucchi, G. & Aglioti, S. M. (2010). The body in the brain revisited. *Experimental Brain Research* 200 (pp. 25-35)
- Botvinick, M. & Cohen, J. (1998). Rubber hands \`feel´ touch that eyes see. *Nature* 391 (p.756)
- Brace, I. (2004). Questionnaire *Design: how to plan, structure and write survey material for effective market research*. London: Kogan Page Ltd. Online through AAU: http://site.ebrary.com/lib/aalborguniv/docDetail.action
- Brace, N., Kemp, R. & Snelgar, R. (2006). SPSS for Psychologists (3rd ed.). Hampshire: Palgrave Macmillian
- Brodie, E. E., Whyte, A. & Niven, C. A. (2007). Analgesia through the looking-glass? A randomized controlled trial investigation the effect of viewing a \`virtual´ limb upon phantom limb pain, sensation and movement. *European Journal of Pain* 11 (pp. 428-436)
- Brodie, E. E, Whyte, A. & Waller, B. (2003). Increased motor control in phantom leg in humans results from the visual feedback of a virtual leg. *Neuroscience Letters* 341 (pp. 167-169)
- Buccion, G., Binkofski, F. & Riggio, L. (2004). The mirror neuron system and action recognition. *Brain and Language* 89 (pp. 370-376)

- Butler, D. (2009a). *Mirror Box Therapy* (7.03 minutes). Uploaded the 04.08.2009 by the Noigroup99. Downloaded from http://wn.com/Mirror_Box_Therapy_with_David_Butler the 01.05.2011
- Butler, D. (2009b). *Graded Motor Imagery* (part 1-4, 40 minutes). David Butlers presentation of Graded Motor Imagery at the March 2009 Fysioterapeuten Conference in Denmark. Uploaded the 19.06.2009 by Noigroup99. Downloaded from http://wn.com/Mirror_Box_Therapy_with_David_Butler the 01.05.2011
- Casale, R., Damiani, C & Rosati, V. (2009). Mirror Therapy in the Rehabilitation of Lower-Limb Amputation. *American Journal of Physical Medicine & Rehabilitation* 88(10) (pp. 837-842)
- Cattaneo, L. & Rizzolatti, G. (2009). The Mirror Neuron System. *Archives of Neurology* 66(5) (pp. 557-560)
- Chan, B.L., Witt, R., Charrow, A.P., Magee, A., Howard, R., Pasquina, P.F., Heilman, K.M. & Tsao, J.W. (2007). Mirror Therapy for Phantom Limb Pain. *The New England Journal of Medicine* 357(21) (pp. 2206-2207)
- Christoffersen, G. & Petrini, L. (in press). Subjective Experience Questionnaire.
- Coolican, H. (2004). Research methods and Statistics in Psychology (4 ed.). London: Hodder Arnold (pp. 313-347)
- de Vignemont, F. (2010). Body schema and body image - Pros and cons. *Neuropsychologia* 48 (pp.669-680)
- Dohle, C., Püllen, J., Nakaten, A., Küst, J., Rietz, C. & Karbe, H. (2009). Mirror Therapy Promotes Recovery From Severe Hemiparesis: A Randomized Controlled Trial. *Neurorehabilitation and Neuro Repair* 23(3) (pp. 209-217)
- Egsgaard, L. L., Petrini, L., Christoffersen, G. & Arendt-Nielsen, L. (in press). *Cortical Responses to the Mirror Box Illusion: A High-Resolution EEG study* (pp. 1-31)
- Ehrsson, H. H., Holmes, N. P. & Passingham, R. E. (2005). Touching a Rubber Hand: Feelings of Body Ownership is Associated with Activity in Multisensory Brain Areas. *The Journal of Neuroscience* 25(45) (pp. 10564-10573)
- Ehrsson, H. H., Spence, C. & Passingham, R. E. (2004). That´s My Hand! Activity in Premotor Cortex Reflects Feelings of Ownership of a Limb. *Science* 305 (pp. 875-877)
- Ehrsson, 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. *PNAS* 104(23) (pp.9828-9833)

- Eng, K., Siekierka, E., Pyk, P., Chevrier, E., Hauser , Y., Cameirao, M., Holper, L., Hagni, K.., Zimmerli, L., Duff, A., Schuster, K., Bassetti, C., Verschure, P. & Kiper, D. (2007). Interactive visuo-motor therapy system for stroke rehabilitation. *Medical and Biological Engineering & Computing* 45 (pp. 901–907)
- Ezendam, D., Bongers, R.M. & Jannink, M.J.A. (2009). Systematic review of the effectiveness of mirror therapy in upper extremity function. *Disability and Rehabilitation* 31(26) (pp. 2135-2149)
- Feltham, M. G., Ledebt, A., Deconinck, F. J. A. & Savelsbergh, G. J. P. (2010). Mirror visual feedback induces lower neuromusculare activity in children with spastic hemiparetic cerebral palsy. Research in Developmental Disability 31 (pp.1525-1535)
- Flor, H. (2002). Phantom-limb pain: characteristics, causes, and treatment. *Lancet Neurology* 1 (pp. 182-189)
- Flor, H. & Diers, M. (2009). Sensorimotor training and cortical reorganization. *Neuro Rehabilitation* 25 (pp. 19-27)
- Gallese, V. & Sinigaglia, C. (2010). The bodily self as a power for action. *Neuropsychologia* 48 (pp. 746-755)
- Garry, M. I., Loftus, A. & Summers, J. J. (2005). Mirror, mirror on the wall: viewing a mirror reflection of unilateral hand movements facilitates ipsilateral M1 excitability. *Experimental Brain Research* 163 (pp. 118-122)
- Gerlach, C., Starrfelt, R., Gade, A. & Pedersen, P. M. (2009). Neuropsykologi: Begrebernes og metodernes historie og udvikling. In A. Gade, C. Gerlach, R. Starrfelt & P. M. Pedersen (eds) *Klinisk neuropsykologi* (pp. 2-12). København: Frydenlund
- Gibson, J. J. (1962). Observations on active touch. *Psychological Review* 69(6) (pp. 477-491)
- Giraux, P. & Sirigu, A. (2003). Illusory movements of the paralyzed limb restore motor cortex activity. *NeuroImage* 20 (pp. 107–111)
- Guterstam, A., Petkova, V. I. & Ehrsson, H. H. (2011). The Illusion of Owing a Third Arm. *PLoS ONE* 6(2) (pp. 1-11)
- Haggard, P. & Tsakiris, M. (2009). The Experience of Agency. *Current directions in Psychological Science* 18(4) (pp.242-246)
- Jeannerod, M. (2001). Neural Simulation of Action: A Unifying Mechanism for Motor Cognition. *NeuroImage* 20 (pp. 103-109)
- Joseph, R. (2000). *Neuropsychiatry, Neuropsychology, Clinical Neuroscience* (3rd ed.). New York: Academic Press

- Lenggenhager, B., Tadi, T., Metzinger, T. & Blanke, O. (2007). Video Ergo Sum: Manipulating Bodily Self-Consciousness. *Science* 317 (pp. 1096-1099)
- Lieberman, I. (2009). *Mirror box therapy exercises* (2.45 minutes). Uploaded the 16.09.2009 by Ilan 1966. Downloaded from http://wn.com/Mirror_Box_Therapy_with_David_Butler the 01.05.2011
- Longo, M. R., Betti, V., Aglioti, S. M. & Haggard, P. (2009). Visually Induced Analgesia: Seeing the Body Reduces Pain. *The Journal of Neuroscience* 29(39) (pp.12125–12130)
- Lotze, M. & Moseley, G.L. (2007). Role of Distorted Body Image in Pain. *Current Rheumatology Reports* 9 (pp. 488-496)
- Karmarkar, A. & Lieberman, I. (2006). Mirror box therapy for complex regional pain syndrome. *Anaesthesia* 61 (pp. 412-413)
- Kolb, B. & Whishaw, I. Q. (2009). *Fundamentals of human Neuropsychology* (6th ed.). New York: Worth publishers
- Mancini, F., Longo, M., Kammers, M. & Haggard, P. (2011). Visual Distortion of Body Size Modulates Pain Perception. *Psychological Science*
- Matthys, K., Smits, M., Van der Geest, J., Van der Lugt, A., Seurinck, R., Stam, H. J. & Selles, R. W. (2009). Mirror-Induced Visual Illusion of Hand Movements: A Functional Magnetic Resonance Imaging Study. *Archive of Physical Medicine and Rehabilitation* 90 (pp. 675-681)
- McCabe, C. (2010). Mirror Visual Feedback Therapy. A practical Approach. *Journal of Hand Therapy* (pp. 170-179)
- McCabe, C. S. & Blake, D. R. (2004). Evidence for a Mismatch Between the Brain´s Movement Control System and Sensory System As an Explanation for Some Pain-related Disorders. *Current pain and headache Reports* 11(2) (pp.104-108)
- McCabe, C. S., Haigh, R. C., Halligan, P. W. & Blake, D. R. (2005). Simulation sensory-motor incongruence in healthy volunteers: implications for a cortical model of pain. *Rheumatology* 44 (pp. 509-516)
- McCabe, C. S., Haigh, R. C., Ring, E. F. J., Halligan, P. W., Wall, P. D & Blake, D. R. (2003). A controlled pilot study of the utility of mirror visual feedback in the treatment of complex regional pain syndrome (type 1). *Rheumatology* 42 (pp. 97-101)
- Mercier, C. & Sirigu, A. (2009). Training With Virtual Feedback to Alleviate Phantom Limb Pain. *Neurorehabilitation and Neural Repair* 23(6) (pp. 587-594)

- Merzenich, M. M., Kaas, J. H, Wall, J. T., Nelson, J. R., Sur, M., & Felleman, D. (1983a). Topographic reorganizations of somatosensory cortical areas b3 and 1 in adult monkeys following restricted deafferentation. *Neuroscience* 8 (1) (pp. 33-55)
- Merzenich, M. M., Kaas, J. H, Wall, J. T., Sur, M., Nelson, J. R. & Felleman, D. J. (1983b). Progression of change following median nerve section in the cortical representation of the hand in areas b3 and 1 in adult owl and squirrel monkeys. *Neuroscience* 10(3) (pp. 639-665)
- Michielsen, M. E.,Selles, R. W., van der Geest, J. N., Eckhardt, M., Yavuzer, G., Stam, H. J., Smits, M., Ribbers, G. M. & Bussmann, B. J. (2011). Motor Recovery and Cortical Reorganization After Mirror Therapy in Chronic Stroke Patients: A Phase II Randomized Controlled Trials. *Neurorehabilitation and Neural Repair* 25(3) (pp. 223-233)
- Michielsen, M. E., Smits, M., Ribbers, G. M., Stam, H. J., van der Geest, J. N., Bussmann, J. B. J. & Selles, R. D. (2010). The neuronal correlates of mirror therapy: an fMRI study on mirror induced visual illusions in patients with stroke. *Journal of Neurology, Neurosurgery and Psychiatry* 82 (pp. 393-398)
- Montoya, P., Ritter, K., Huse, E., Larbig, W., Braun, C. & Töpfner, S. (1998). The cortical somatotopic map and phantom phenomena in subjects with congenital limb atrophy and traumatic amputees with phantom limb pain. *European Journal of Neuroscience* 10 (pp. 1095-1102)
- Moseley, G. L. (2004a). Graded motor imagery is effective for long-standing regional pain syndrome: a randomized control trial. *Pain* 108 (pp. 192-198)
- Moseley, G. L. (2004b). Why do people with complex regional pain syndrome take longer to recognize their affected hand? *Neurology* 62 (pp. 2182-2186)
- Moseley, G.L. (2006). Graded motor imagery for pathologic pain. Neurology 67 (pp.2119-2134)
- Moseley, G.L., Gallace, A. & Spence, C. (2008). Is mirror therapy all it is cracked up to be? Current evidence and future directions. *Pain* 138(1) (pp. 7-10)
- Moseley, G. L., Parsons, T. J. & Spence, C. (2008). Visual distortion of a limb modulates the pain and swelling evoked by movement. *Current Biology* 18(22) (pp.1047-1048)
- Murray, C.D, Patchick, E., Pettifer, S., Howard, T. & Caillette, F. (2006). *Investigating the efficacy of a virtual mirror box in treating phantom limb pain in a sample of chronic sufferers*. Proc. 6th Intl Conf. Disability, Virtual Reality & Assoc. Tech., Esbjerg (pp. 167-174)
- Nikolajsen, L. & Jensen, T. S. (2001). Phantom limb pain. *British Journal of Anaesthesia* 87(1) (pp. 107-116)

- Nico, D., Daprati, E., Rigal, F., Parsons, L., & Sirigu, A. (2004). Left and right hand recognition in upper limb amputees. *Brain* 127, (pp.120-132)
- The NOI Group (2008). *Recognise*. At: http://recognise.noigroup.com/recognise.
- Pedersen, K. C. (2011a). *Forslag til øvelsesprogram i forbindelse med spejlbehandling, hvor der ønskes bevægetræning*
- Penfield, W. & Boldrey, E. (1937). Somatic Motor and Sensory Representations in the Cerebral Cortex of Man as Studied by Electrical Stimulation. *Brain* (pp. 389-443)
- Pons, T. P., Garraghty, P. E., Ommaya, A. K., Kaas, J. H., Taub, E., & Mishkin, M. (1991). Massive Cortical Reorganization after Sensory Deafferentation in Adult Macaques. *Science* 252(5014) (pp. 1857-1860)
- Ramachandran, V. S. (1994). Phantom Limbs, Neglect Syndromes, Repressed Memories, and Freudian Psychology. *International Review of Neurobiology* 37 (pp. 291-333)
- Ramachandran, V. S. & Altschuler, E. L. (2009). The use of visual feedback, in particular mirror visual feedback, in restoring brain functioning. *Brain* 132 (pp. 1693-1710)
- Ramachandran, V.S. , Brang, D, & McGeoch, P.D.(2010). Size Reduction Using Mirror Visual Feedback (MVF) Reduces Phantom Pain. *Neurocase* 15(5) (pp. 357–360)
- Ramachandran, V. S. & Hirstein, W. (1998). The perception of phantom limbs. The D.O. Hebb lecture. Brain 121 (pp. 1603-1630)
- Ramachandran, V.S. & Rogers- Ramachandran, D. (1996). Synaesthesia in phantom limbs induced with mirrors. *Biological Science* 263(1369) (pp. 377-386)
- Ramachandran, V. S., Rogers-Ramachandran, D. & Cobb, S. (1995). Touching the phantom limb. *Nature* 377 (pp. 489-490)
- Ramachandran, V. S., Rogers-Ramachandran, D. & Stewart, M. (1992). Perceptual Correlates of Massive Cortical Reorganization. *Science* 258 (pp. 1159-1160)
- Ramachandran, V.S. & Seckel, E.L. (2010). Using mirror visual feedback and virtual reality to treat fibromyalgia. Medical Hypotheses. *Pain* 149 (pp.171-172)
- Reed, C. L., Stone, V. E. & McGoldrick, J. E. (2006). Not Just Posturing. Configural Processing of the Human Body. G, Knoblich, I. M. Thornton, M. Grosjean & M. Shiffrar (eds.), *Human body perception from the inside out* (pp. 229-258). Oxford: Oxford University Press
- Rizzolati, G., Fadiga, L., Gallese, V. & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research* 3 (pp. 131-141)
- Rock, I. & Victor, J. (1964). Vision and Touch: An Experimentally Created Conflict between the Two Senses. *Science* 143(3606) (p. 594-596)

- Roland, P. E. (2003). *Brain Activation*. New York: Wiley-Liss, Inc. (pp. 237-268)
- Rosén, B. & Lundborg, G. (2005). Training with a mirror in rehabilitation of the hand. *Journal of Plastic and Reconstructive Surgery and Hand Surgery* 39 (pp. 104-/108)
- Rothgangel, A. S., Braun, S. M., Beurskens, A. J., Seitz, R. J. & Wade, D. T. (2010). The clinical aspects of mirror therapy in rehabilitation: a systematic review of the literature. *International Journal of Rehabilitation Research* 34(1) (pp. 1-13)
- Sathian, K., Greenspan, A.I. & Wolf, S.L. (2000). Doing It with Mirrors: A Case Study of a Novel Approach to Neurorehabilitation. *Neurorehabilitation and Neural Repair* 14
- Sato, K., Fukumori, S., Matsusaki, T., Maruo, T., Ishikawa, S., Nishie, H., Takata, K., Mizuhara, H., Mizobuchi, S., Nakatsuka, H., Matsumi, M., Gofuku, A., Yokoyama, M. & Morita, K. (2010). Nonimmersive Virtual Reality Mirror Visual Feedback Therapy and Its Application for the Treatment of Complex Regional Pain Syndrome: An Open-Label Pilot Study. *Pain Medicine* 11 (pp. 622-629)
- Schwoebel, J., Buxbaum, L. J. & Coslett, H. B. (2004). Representations of the Human Body in the Production and Imitation of Complex Movements. *Cognitive neuropsychology* 21(2,3,4) (pp. 285-298)
- Schwoebel, J. & Coslett, H. B. (2005). Evidence for Multiple, Distinct Representations of the Human Body. *Journal of Cognitive Neuroscience* 17(4) (pp. 543-553)
- Seidel, S., Kasprian, G., Sycha, T. & Auff, E. (2009). Spiegeltherapie bei Phantomschmerzen: Eine systematische Übersichtarbeit. *The Middle European Journal of Medicine* 121 (pp. 440-444)
- Shumway-Cook, A. & Woollacott, M. H. (2001). Motor Control. Theory and Practical Applications (2.ed.). Philadelphia: Lippincott Williams & Wilkins (pp.1-127)
- Slater, M., Perez-Marcos, D., Ehrsson, H. H. & Sanchez-Vives, M. V. (2008). Towards a digital body: the virtual arm illusion. *Frontiers in Human Neuroscience* 2 (pp. 1-8)
- Stevens, J. A. & Stoykov, M. E. P. (2003). Using Motor Imagery in the Rehabilitation of Hemiparesis. *Archives of Physical Medicine and Rehabilitation* 84 (pp. 1090-1092)
- Sumitani, M., Miyauchi, S., McCabe, C. S., Shibata, M., Maeda, L., Saitoh, Y., Tashiro, T. & Mashimo, T. (2008). Mirror visual feedback alleviates deafferentation pain depending on qualitative aspects of the pain: a preliminary report. *Rheumatology* 47 (pp. 1038-1043)
- Sütbeyaz, S., Yavuzer, G., Sezer, N. & Koseoglu, F. (2007). Mirror Therapy Enhances Lower-Extremity Motor Recovery and Motor Functioning After Stroke: a Randomized Controlled Trial. *Archives of Physical Medicine and Rehabilitation* 88 (pp. 555-559)

- Taub, E., Uswatte, G. & Pidikiti, R. (1999). Constraint-Induced Movement Therapy: A New Family of Techniques with Broad Application to Physical Rehabilitation. A Clinical Review. *Journal of Rehabilitation Research & Development* 36(3) (pp. 1-21)
- Tsakiris, M., Prabhu, G. & Haggard, P. (2006). Having a body versus moving your body: How agency structures body-ownership. *Consciousness and Cognition* 15 (pp. 423–432)
- Walker, I. (2007). *Statistics for Psychology*. At: http://staff.bath.ac.uk/pssiw/stats2/page2/page14/page14.html.
- Wall, P. D. & Wolstencroft, J. H. (1977). The Presence of Ineffective Synapses and the Circumstances which Unmask Them. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 278(961) (pp. 361-372)
- Weinerberg, M. (2010). *Mirror Therapy for chronic pain* (3.28 minutes). Uploaded the 13.11.2010 by cszar. Downloaded from http://wn.com/Mirror_Box_Therapy_with_David_Butler the 01.05.2011
- Villemure, C. & Bushnell, M. C. (2002). Cognitive modulation of pain: how do attention and emotion influence pain processing? Pain 95 (pp. 195-199)
- Weeks, S. R. & Tsao, J.W. (2010). Incorporation of another person's limb into body image relieves phantom limb pain: A case study. *Neurocase* 16(6) (pp. 461-465)
- Urbaniak, G. C. & Plous, S. (2007). *Research Ramndomizer*. At: http://www.randomizer.org/about.htm
- Yavuzer, G., Selles, R., Sezer, N., Sütbeyaz, S., Bussmann, J. B., Köseglu, F., Atay, M. B. & Stam, H. J. (2008). Mirror Therapy Improves Hand Function in Subacute Stroke: A Randomized Controlled Trials. *Archives of Physical Medicine and Rehabilitation* 89 (pp. 393-398)

11.0 Literature

11.1 Old literature

Altschuler, E.L. & Hu, J. (2008). Mirror therapy in a patient with a fractured wrist and no active wrist extension. *Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery* 42 (pp.110-111)

- Altschuler, E. L. & Ramachandran, V. S. (2007). Last but not least. *Perception* 36 (pp. 632-634)
- Botvinick, M. & Cohen, J. (1998). Rubber hands `feel´ touch that eyes see. *Nature* 391 (p.756)
- Brace, N., Kemp, R. & Snelgar, R. (2006). SPSS for Psychologists (3rd ed.). Hampshire: Palgrave Macmillian (pp.1-25, 69-85, 161-221)
- Brodie, E. E., Whyte, A. & Niven, C. A. (2007). Analgesia through the looking-glass? A randomized controlled trial investigation the effect of viewing a `virtual´ limb upon phantom limb pain, sensation and movement. *European Journal of Pain* 11 (pp. 428-436)
- Chan, B.L., Witt, R., Charrow, A.P., Magee, A., Howard, R., Pasquina, P.F., Heilman, K.M. & Tsao, J.W. (2007). Mirror Therapy for Phantom Limb Pain. *The New England Journal of Medicine* 357(21) (pp. 2206-2207)
- Coolican, H. (2004). *Research methods and Statistics in Psychology* (4 ed.). London: Hodder Arnold (pp. 179-181+313-347)
- Eng, K., Siekierka, E., Pyk, P., Chevrier, E., Hauser, Y., Cameirao, M., Holper, L., Hagni, K.., Zimmerli, L., Duff, A., Schuster, K., Bassetti, C., Verschure, P. & Kiper, D. (2007). Interactive visuo-motor therapy system for stroke rehabilitation. *Medical and Biological Engineering & Computing* 45 (pp. 901–907)
- Ezendam, D., Bongers, R.M. & Jannink, M.J.A. (2009). Systematic review of the effectiveness of mirror therapy in upper extremity function. *Disability and Rehabilitation* 31(26) (pp. 2135-2149)
- Funase, K., Tabira, T., Higashi, T., Liang, N. & Kasai, T. (2007). Increased corticospinal excitability during direct observation of self-movement and indirect observation with a mirror box. *Neuroscience Letters* 419 (pp. 108–112)
- Hudson, M. L., McCormick, K., Zalucki, N. & Moseley, G. L. (2006). Expectation of pain replicates the effect of pain in a hand laterality recognition task: Bias in information processing towards the painful side? *European Journal of Pain* 10 (pp. 219-224)

- Lotze, M. & Moseley, G.L. (2007). Role of Distorted Body Image in Pain. *Current Rheumatology Reports* 9 (pp. 488-496)
- McCabe, C.S., Haigh, R. C., Halligan, P. W. & Blake, D. R. (2003). Referred sensation in patients with complex regional pain syndrome type 1. *Rheumatology* 42 (pp. 1067–1073)
- McCabe, C. S., Haigh, R. C., Ring, E. F. J., Halligan, P. W., Wall, P. D & Blake, D. R. (2003). A controlled pilot study of the utility of mirror visual feedback in the treatment of complex regional pain syndrome (type 1). *Rheumatology* 42 (pp. 97-101)
- Mercier, C. & Sirigu, A. (2009). Training With Virtual Feedback to Alleviate Phantom Limb Pain. *Neurorehabilitation and Neural Repair* 23(6) (pp. 587-594)
- Moseley, G. L. (2004a). Graded motor imagery is effective for long-standing regional pain syndrome: a randomized control trial. *Pain* 108 (pp. 192-198)
- Moseley, G. L. (2004b). Why do people with complex regional pain syndrome take longer to recognize their affected hand? *Neurology* 62 (pp. 2182-2186)
- Moseley, G.L. (2006). Graded motor imagery for pathologic pain. *Neurology* 67 (pp.2119-2134)
- Moseley, G.L. (2007). Using visual illusion to reduce at-level neuropathic pain in paraplegia. *Pain* 130 (pp. 294–298)
- Moseley, G.L., Gallace, A. & Spence, C. (2008). Is mirror therapy all it is cracked up to be? Current evidence and future directions. *Pain* 138(1) (pp. 7-10)
- Murray, C.D, Patchick, E., Pettifer, S., Howard, T. & Caillette, F. (2006). *Investigating the efficacy of a virtual mirror box in treating phantom limb pain in a sample of chronic sufferers*. Proc. 6th Intl Conf. Disability, Virtual Reality & Assoc. Tech., Esbjerg (pp. 167-174) **8 pages**
- Nico, D., Daprati, E., Rigal, F., Parsons, L., & Sirigu, A. (2004). Left and right hand recognition in upper limb amputees. *Brain* 127, (pp.120-132)
- Penfield, W. & Boldrey, E. (1937). Somatic Motor and Sensory Representations in the Cerebral Cortex of Man as Studied by Electrical Stimulation. *Brain* (pp. 389-443)
- Ramachandran, V. S. & Altschuler, E. L. (2009). The use of visual feedback, in particular mirror visual feedback, in restoring brain functioning. *Brain* 132 (pp. 1693-1710)
- Ramachandran, V.S., Brang, D, & McGeoch, P.D. (2010). Size Reduction Using Mirror Visual Feedback (MVF) Reduces Phantom Pain. *Neurocase* 15(5) (pp. 357–360)
- Ramachandran, V. S. & Hirstein, W. (1998). The perception of phantom limbs. The D.O. Hebb lecture. *Brain* 121 (pp. 1603-1630)

- Ramachandran, V.S. & Rogers- Ramachandran, D. (1996). Synaesthesia in phantom limbs induced with mirrors. *Biological Science* 263(1369) (pp. 377-386)
- Ramachandran, V. S., Rogers-Ramachandran, D. & Cobb, S. (1995). Touching the phantom limb. *Nature* 377 (pp. 489-490)
- Ramachandran, V. S., Rogers-Ramachandran, D. & Stewart, M. (1992). Perceptual Correlates of Massive Cortical Reorganization. *Science* 258 (pp. 1159-1160)
- Ramachandran, V.S. & Seckel, E.L. (2010). Using mirror visual feedback and virtual reality to treat fibromyalgia. Medical Hypotheses. *Pain* 149 (pp.171-172)
- Rock, I. & Victor, J. (1964). Vision and Touch: An Experimentally Created Conflict between the Two Senses. *Science* 143(3606) (p. 594-596)
- Rosén, B. & Lundborg, G. (2005). Training with a mirror in rehabilitation of the hand. *Journal of Plastic and Reconstructive Surgery and Hand Surgery* 39 (pp. 104-108)
- Sathian, K., Greenspan, A.I. & Wolf, S.L. (2000). Doing It with Mirrors: A Case Study of a Novel Approach to Neurorehabilitation. *Neurorehabilitation and Neural Repair* 14 (pp.73-76)
- Schwoebel, J., Coslet, H. B., Bradt, J., Freidman, R. & Dileo, C. (2002). Pain and the body schema: Effects of pain severity on mental representations of movement. *Neurology* 59 (pp.775-777)
- Stevens, J. A. & Stoykov, M. E. P. (2003). Using Motor Imagery in the Rehabilitation of Hemiparesis. *Archives of Physical Medicine and Rehabilitation* 84 (pp. 1090-1092)
- Sumitani, M., Miyauchi, S., McCabe, C. S., Shibata, M., Maeda, L., Saitoh, Y., Tashiro, T. & Mashimo, T. (2008). Mirror visual feedback alleviates deafferentation pain depending on qualitative aspects of the pain: a preliminary report. *Rheumatology* 47 (pp. 1038-1043)
- Tsakiris, M., Prabhu, G. & Haggard, P. (2006). Having a body versus moving your body: How agency structures body-ownership. *Consciousness and Cognition* 15 (pp. 423–432)

479 pages

11.2 New literature

- Acerra, N. E. & Moseley, G. L. (2005). Dysynchiria: Watching the mirror image of the unaffected limb elicits pain on the affected side. *Neurology* 65 (pp. 751-753)
- Altschuler, E. L. (2005). Interaction of vision and movement via a mirror. *Perception* 34 (pp. 1153-1155)

- Altschuler, E. L., Wisdom, S. B., Stone, L., Foster, C., Galasko, D., Llewellyn, M. E. & Ramachandran, V. S. (1999). Rehabilitation of hemiparesis after stroke with a mirror. *The Lancet* 353 (pp. 2035-2036)
- Apkarian, V. A., Bushnell, M. C., Treede, R. & Zubieta, J. (2005). Human brain mechanisms for pain of pain perception and regulation in health and disease. *European Journal of Pain* 9 (pp. 463-484)
- Balconi, M. & Bottolotti, A. (2010). Body and Self-awareness: Functional and Dysfunctional Mechanisms. In M. Balconi (Ed.) *Neuropsychology of the Sense of Agency: From Consciuosness to Action* (pp. 173-189). Milan: Springer
- Berlucchi, G. & Aglioti, S. M. (2010). The body in the brain revisited. *Experimental Brain Research* 200 (pp. 25-35)
- Beyer, N., Lund, H. & Klinge, K. (2010). Træning i fysioterapeutisk praksis. In H. Lund, I. B. Bjørnlund & N. E. Sjöberg (Eds.) *Basisbog i fysioterapi* (pp.281-286). København: Munksgaard
- Brace, I. (2004). Questionnaire *Design: how to plan, structure and write survey material for effective market research*. London: Kogan Page Ltd.
- Brodie, E. E, Whyte, A. & Waller, B. (2003). Increased motor control in phantom leg in humans results from the visual feedback of a virtual leg. *Neuroscience Letters* 341 (pp. 167-169)
- Brugger, P. (2006). From Phantom Limb to Phantom Body. Varities of Extracorporeal Awareness. G, Knoblich, I. M. Thornton, M. Grosjean & M. Shiffrar (eds.), *Human body perception from the inside out* (pp. 171-209). Oxford: Oxford University Press
- Buccion, G., Binkofski, F. & Riggio, L. (2004). The mirror neuron system and action recognition. *Brain and Language* 89 (pp. 370-376)
- Buccino, G., Solodkin, A. & Small, S. L. (2006). Functions of the Mirror Neuron System: Implications for Neurorehabilitation. *Cognitive and Behavioral Neurology* 19(1) (pp. 55-63)
- Carifio, J. & Perla, R. (2008). Resolving the 50-year debate around using and misusing Likert scales. *Medical Education* 42 (pp. 1150-1152)
- Casale, R., Damiani, C & Rosati, V. (2009). Mirror Therapy in the Rehabilitation of Lower-Limb Amputation. *American Journal of Physical Medicine & Rehabilitation* 88(10) (pp. 837-842)
- Cattaneo, L. & Rizzolatti, G. (2009). The Mirror Neuron System. *Archives of Neurology* 66(5) (pp. 557-560)

- Christoffersen, G. & Petrini, L. (in press). Subjective Experience Questionnaire.
- de Vignemont, F. (2010). Body schema and body image - Pros and cons. *Neuropsychologia* 48 (pp.669-680)
- de Vignemont, F. (2011). Embodiment, ownership and disownership. *Consciousness and Cognition* 20 (pp. 82-93)
- de Vignement, F. & Fourneret, P. (2004). The sense of agency: A philosophical and empirical review of the "Who" system. Consciousness and Cognition 13 (pp. 1-19)
- de Vignemont, F., Tsakiris, M. & Haggard, P. (2006). Body Mereology. G, Knoblich, I. M. Thornton, M. Grosjean & M. Shiffrar (eds.), *Human body perception from the inside out* (pp. 147-170). Oxford: Oxford University Press
- Dohle, C., Püllen, J., Nakaten, A., Küst, J., Rietz, C. & Karbe, H. (2009). Mirror Therapy Promotes Recovery From Severe Hemiparesis: A Randomized Controlled Trial. *Neurorehabilitation and Neuro Repair* 23(3) (pp. 209-217)
- Dum, R. P. & Strick, P. L. (2005). Motor Areas in the Frontal Lobe: The Anatomical Substrate for the Central Control of Movement. In A. Riehle & E. Vaadia (eds.), *Motor Cortex in Voluntary Movements: A Distributed System for Distributed Functions* (pp.3-47). Boca Raton: CRC Press
- Egsgaard, L. L., Petrini, L., Christoffersen, G. & Arendt-Nielsen, L. (in press). *Cortical Responses to the Mirror Box Illusion: A High-Resolution EEG study* (pp. 1-31)
- Ehrsson, H. H. (2011). The Experimental Induction of Out-of-Body Experiences. *Science* 317 (pp. 1048)
- Ehrsson, H. H., Holmes, N. P. & Passingham, R. E. (2005). Touching a Rubber Hand: Feelings of Body Ownership is Associated with Activity in Multisensory Brain Areas. *The Journal of Neuroscience* 25(45) (pp. 10564-10573)
- Ehrsson, H. H., Spence, C. & Passingham, R. E. (2004). That´s My Hand! Activity in Premotor Cortex Reflects Feelings of Ownership of a Limb. *Science* 305 (pp. 875-877)
- Ehrsson., 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. *PNAS* 104(23) (pp.9828-9833)
- Fadiga, L., Fogassi, L., Pavesi, G. & Rizzolati, G. (1995). Motor Facilitation during Action Observation: A Magnetic Stimulation Study. *Journal of Neurophysiology* 73(6) (pp. 2608-2611)

- Feltham, M. G., Ledebt, A., Deconinck, F. J. A. & Savelsbergh, G. J. P. (2010). Mirror visual feedback induces lower neuromusculare activity in children with spastic hemiparetic cerebral palsy. Research in Developmental Disability 31 (pp.1525-1535)
- Fink, G. R., Marshall, J. C., Halligan, P. H., Frith, C. D., Driver., D., Frackowiak, R. S. J. &. Dolan, R. J. (1999).The neural consequences of conflict between intention and the senses. *Brain* 122 (pp. 497-512)
- Flor, H. (2002). Phantom-limb pain: characteristics, causes, and treatment. *Lancet Neurology* 1 (pp. 182-189)
- Flor, H. & Diers, M. (2009). Sensorimotor training and cortical reorganization. *Neuro Rehabilitation* 25 (pp. 19-27)
- Franz, E. A. & Packman, T. (2004). Fooling the brain into thinking it sees both hands moving enhances bimanual spatial coupling. *Experimental Brain Research* 157 (pp. 174-180)
- Gallagher, S. (2000). Philosophical conceptions of the self: implications for cognitive science. *Trends in Cognitive Sciences* 4(1) (pp. 14-21)
- Gallese, V. (2000). The Inner Sense of Action: Agency and Motor Representations. *Journal of Consciousness Studies* 7(10) (pp.23-40)
- Gallese, V., Fadiga, L., Fogassi, L. & Rizzolatti, G. (1996). Action Recognition in the Premotor Cortex. *Brain* 119 (pp. 593-609)
- Gallese, V. & Sinigaglia, C. (2010). The bodily self as a power for action. *Neuropsychologia* 48 (pp. 746-755)
- Garry, M. I., Loftus, A. & Summers, J. J. (2005). Mirror, mirror on the wall: viewing a mirror reflection of unilateral hand movements facilitates ipsilateral M1 excitability. *Experimental Brain Research* 163 (pp. 118-122)
- Gerlach, C., Starrfelt, R., Gade, A. & Pedersen, P. M. (2009). Neuropsykologi: Begrebernes og metodernes historie og udvikling. In A. Gade, C. Gerlach, R. Starrfelt & P. M. Pedersen (eds) *Klinisk neuropsykologi* (pp. 2-12). København: Frydenlund
- Gibson, J. J. (1962). Observations on active touch. *Psychological Review* 69(6) (pp. 477-491)
- Giraux, P. & Sirigu, A. (2003). Illusory movements of the paralyzed limb restore motor cortex activity. *NeuroImage* 20 (pp. 107–111)
- Giummarre, M. J., Georgiou-Karistianis, N, Nicholls, M. & Bradshaw, J. L. (2011). The third hand: Ownership of a rubber hand in addition to the existing (phantom) hand. *Cortex* 47 (pp. 998-1000)

- Giummarra, M. J., Gibson, S. J., Karistianis, N. G. & Bradshaw, J. L. (2007). Central mechanisms in phantom limb perception: The past, present and future. *Brain Research Review* 54 (pp. 219-232)
- Graziano, M. S. A. (1999). Where is my arm? The relative role of vision and proprioception in the neuronal representation of limb position. *Proc. Natl. Acad. Sci.* 96 (pp. 10418-10421)
- Guterstam, A., Petkova., V. I. & Ehrsson, H. H. (2011). The Illusion of Owing a Third Arm. *PLoS ONE* 6(2) (pp. 1-11)
- Haans, A., IJsselsteijn, W. A. & de Kort, Y. A. W. (2008). The effect of similarities in skin texture and hand shape on perceived ownership of a fake limb. *Body Image* 5 (pp. 389-394)
- Haggard, P. & Tsakiris, M. (2009). The Experience of Agency. Feelings, Judgments, and Responsibility. *Current Directions in Psychological Science* 18(4) (pp. 242-246)
- Hellström, C. (2001). Affecting the Future: Chronic Pain and Perceived Agency in a Clinical Setting. *Time & Society* 10(1) (pp. 77-92)
- Holmes, N. P., Crozier, G. &Spence, C. (2004). When mirrors lie: 'Visual capture' of arm position impairs reaching performance. *Cognitive, Affective, & Behavioural Neuroscience* 4(2) (pp.193-206)
- Holmes, N. P. & Spence, C. (2005). Visual bias of unseen hand position with a mirror: spatial and temporal factors. *Experimental Brain Research* 155 (pp. 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. *Perceptual Psychophysiology* 68(4) (pp. 685–701)
- Jamieson, S. (2004). Likert Scales: how to (ab)use them. *Medical Education* 38 (pp. 1217-1218)
- Jeannerod, M. (2001). Neural Simulation of Action: A Unifying Mechanism for Motor Cognition. *NeuroImage* 20 (pp. 103-109)
- Joseph, R. (2000). *Neuropsychiatry, Neuropsychology, Clinical Neuroscience* (3rd ed.). New York: Academic Press
- Kammer, M. P. M., de Vignemont, F. & Hagard, P. (2010). Cooling the Thermal Grill Illusion through Self-Touch. *Current Biology* 20(20) (pp. 1819-1822)
- Karmarkar, A. & Lieberman, I. (2006). Mirror box therapy for complex regional pain syndrome. *Anaesthesia* 61 (pp. 412-413)

- Keysers, C., Wicker, B., Gazzola, V., Anton, J., Fogassi, L. & Gallese, V. (2004). A Touching Sight: SII/PV Activation during the Observation and Experience of Touch. *Neuron*. 42, (pp. 335–346)
- Kolb, B. & Whishaw, I. Q. (2009). *Fundamentals of human Neuropsychology* (6th ed.). New York: Worth publishers (pp. 1-28, 223-244)
- Lenggenhager, B., Tadi, T., Metzinger, T. & Blanke, O. (2007). Video Ergo Sum: Manipulating Bodily Self-Consciousness. *Science* 317 (pp. 1096-1099)
- Longo, M. R., Betti, V., Aglioti, S. M. & Haggard, P. (2009). Visually Induced Analgesia: Seeing the Body Reduces Pain. *The Journal of Neuroscience* 29(39) (pp.12125–12130)
- Makin, T. R., Holmes, N. P. & Ehrsson, H. H. (2008). On the other hand: Dummy hands and peripersonal space. *Behavioral Brain Research* 191 (pp. 1-10)
- Mancini, F., Longo, M. R., Kammers, M. P. M. & Haggard, P. (2011). Visual Distortion of Body Size Modulates Pain Perception. *Psychological Science* (pp.1-6)
- Maravita, A., Spence, C. & Driver, J. (2003). Multisensory integration and the Body Schema: Close to Hand and Within Reach. *Current Biology* 13 (pp. 531-539)
- Matlin, M. W. (2005). *Cognition* (6th ed.). John Wiley & Sons, Inc. (pp. 207-225)
- Matthys, K., Smits, M., Van der Geest, J., Van der Lugt, A., Seurinck, R., Stam, H. J. & Selles, R. W. (2009). Mirror-Induced Visual Illusion of Hand Movements: A Functional Magnetic Resonance Imaging Study. *Archive of Physical Medicine and Rehabilitation* 90 (pp. 675-681)
- McCabe, C. (2010). Mirror Visual Feedback Therapy. A practical Approach. *Journal of Hand Therapy* (pp. 170-179)
- McCabe, C. S. & Blake, D. R. (2004). Evidence for a Mismatch Between the Brain´s Movement Control System and Sensory System As an Explanation for Some Pain-related Disorders. *Current pain and headache Reports* 11(2) (pp.104-108)
- McCabe, C. S., Cohen, H.. & Blake, D. R. (2007). Somaesthetic disturbances in fibromyalgia are exaggerated by sensory–motor conflict: implications for chronicity of the disease? *Rheumatology* 46 (pp.1587–1592)
- McCabe, C. S., Haigh, R. C., Halligan, P. W. & Blake, D. R. (2005). Simulation sensory-motor incongruence in healthy volunteers: implications for a cortical model of pain. *Rheumatology* 44 (pp. 509-516)
- Merzenich, M. M., Kaas, J. H, Wall, J. T., Nelson, J. R., Sur, M., & Felleman, D. (1983a). Topographic reorganizations of somatosensory cortical areas b3 and 1 in adult monkeys following restricted deafferentation. *Neuroscience* 8 (1) (pp. 33-55)

- Merzenich, M. M., Kaas, J. H, Wall, J. T., Sur, M., Nelson, J. R. & Felleman, D. J. (1983b). Progression of change following median nerve section in the cortical representation of the hand in areas b3 and 1 in adult owl and squirrel monkeys. *Neuroscience* 10(3) (pp. 639-665)
- Michielsen, M. E.,Selles, R. W., van der Geest, J. N., Eckhardt, M., Yavuzer, G., Stam, H. J., Smits, M., Ribbers, G. M. & Bussmann, B. J. (2011). Motor Recovery and Cortical Reorganization After Mirror Therapy in Chronic Stroke Patients: A Phase II Randomized Controlled Trials. *Neurorehabilitation and Neural Repair* 25(3) (pp. 223-233)
- Michielsen, M. E., Smits, M., Ribbers, G. M., Stam, H. J., van der Geest, J. N., Bussmann, J. B. J. & Selles, R. D. (2010). The neuronal correlates of mirror therapy: an fMRI study on mirror induced visual illusions in patients with stroke. *Journal of Neurology, Neurosurgery and Psychiatry* 82 (pp. 393-398)
- Montoya, P., Ritter, K., Huse, E., Larbig., W., Braun, C. & Töpfner, S. (1998). The cortical somatotopic map and phantom phenomena in subjects with congenital limb atrophy and traumatic amputees with phantom limb pain. *European Journal of Neuroscience* 10 (pp. 1095-1102)
- Moseley, G. L., Parsons, T. J. & Spence, C. (2008). Visual distortion of a limb modulates the pain and swelling evoked by movement. *Current Biology* 18(22) (pp.1047-1048) **2 pages**
- Moseley, G. L. & Wiech, K. (2009). The effect of tactile discrimination training is enhanced when patients watch the reflected image of their unaffected limb during training. *Pain* 144 (pp. 314-319)
- Moseley, G. L., Zalucki, N., Birklein, F., Marinus, J., Hilten, J. J. & Ludomajoki, H. (2008). Thinking About Movement Hurts: The Effect of Motor Imagery on Pain and Swelling in People With Chronic Arm Pain. *Arthritis & Rheumatism* 59(5) (pp. 623–631) **9 pages**
- Murray, C. D., Pettifer, F., Howard, T., Patchick, E. L., Caillette, F., Kulkarni, J. & Bamford, C. (2007). The treatment of phantom limb pain using immersive virtual reality: Three case studies. *Disability and Rehabilitation* 29(18) (pp. 1465-1469)
- Nikolajsen, L. & Jensen, T. S. (2001). Phantom limb pain. *British Journal of Anaesthesia* 87(1) (pp. 107-116)
- O´keefe, D. J. (2007). Post Hoc Power, Observed Power, A Priori Power, Retrospective Power, Prospective Power, Achieved Power: Sorting Out Appropriate Uses of Statistical Power Analyses. *Communication Methods and Measures*, I(4) (pp. 291-299)
- Ottosen, A. R., Nielsen, S. S. & Puggård, H. (2008). *En klinisk vejledning for ergo- og fysioterapeutisk behandling af CRPS*. Udarbejdet fra Ergo- og Fysioterapi Afdelingen,

Aalborg Sygehus. Downloaded d. 03.07.2011 from
http://www.aalborgsygehus.rn.dk/NR/rdonlyres/CC851D33-BB2B-4121-BD54-1339F318539A/0/CRPShellepuggaard.pdf

- Parsons, L. M. (1987a). Imagined Spatial Transformation of One's Body. *Journal of Experimental Psychology: General* 116(2) (pp. 172-191)
- Parsons, L. M. (1987b). Imagined Spatial Transformation of One's Hands and Feet. *Cognitive Psychology* 19 (pp. 178-241)
- Parsons, L. M. (2001). Integrating cognitive psychology, neurology and neuroimaging. *Acta Psychologica* 107 (pp. 155-181)
- Pedersen, K. C. (2011a). *Forslag til øvelsesprogram i forbindelse med spejlbehandling, hvor der ønskes bevægetræning* (pp. 1-4). Downloaded 09.09.2011 at www.håndterapi.dk/øvelsesprogrammer.htm
- Pedersen, K. C. (2011b). Spejlbehandling i praksis. *Ergoterapeuten* 5(11) (pp. 38-42)
- Pell, G. (2005). Use and misuse of Likert scales. *Medical Education* 39 (p. 970)
- Pons, T. P., Garraghty, P. E., Ommaya, A. K., Kaas, J. H., Taub, E., & Mishkin, M. (1991). Massive Cortical Reorganization after Sensory Deafferentation in Adult Macaques. *Science* 252(5014) (pp. 1857-1860)
- Ramachandran, V. S. (1994). Phantom Limbs, Neglect Syndromes, Repressed Memories, and Freudian Psychology. *International Review of Neurobiology* 37 (pp. 291-333) **43 pages**
- Ramachandran, V. S. & Brang, D. (2009). Sensations Evoked in Patients With Amputation From Watching an Individual Whose Corresponding Intact Limb Is Being Touched. *Archives of Neurology* 66(10) (pp. 1281-1284)
- Reed, C. L., Stone, V. E. & McGoldrick, J. E. (2006). Not Just Posturing. Configural Processing of the Human Body. G, Knoblich, I. M. Thornton, M. Grosjean & M. Shiffrar (eds.), *Human body perception from the inside out* (pp. 229-258). Oxford: Oxford University Press
- Rijntjes, M., Dettmers, C., Büchel, C., Kiebel, S., Frackowiak, R. S. J., & Weiller, C. (1999). A Blueprint for Movement: Functional and Anatomical Representations in the Human Motor System. *The Journal of Neuroscience* 19(18) (pp. 8043–8048)
- Ritchie, J. R. & Carlson, T. (2010). Mirror, mirror, on the wall, is that even my hand at all? Changes in the afterimage of one´s reflection in a mirror in response to bodily movement. *Neuropsychologia* 48 (pp. 1495-1500)
- Rizzolati, G., Fadiga, L., Gallese, V. & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research* 3 (pp. 131-141)

- Rizzolati, G., Fogassi, L. & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews* 2 (pp.661-670)
- Roland, P. E. (2003). *Brain Activation*. New York: Wiley-Liss, Inc. (pp. 141-267)
- Roland, P., Larsen, B., Lassen, A. & Skinhøj, E. (1980). Supplementary Motor Areas and Other Cortical Areas in Organization of Voluntary Movements in Man. *Journal of Neurophysiology* 43(1) (pp. 118-136)
- Rosenbaum, A. R. (2011). Illusionen om bevægelse kan stimulere til bevægelse. *Ergoterapeuten* 5(11) (pp. 34-37)
- Rothgangel, A. S., Braun, S. M., Beurskens, A. J., Seitz, R. J. & Wade, D. T. (2010). The clinical aspects of mirror therapy in rehabilitation: a systematic review of the literature. *International Journal of Rehabilitation Research* 34(1) (pp. 1-13)
- Sato, K., Fukumori, S., Matsusaki, T., Maruo, T., Ishikawa, S., Nishie, H., Takata, K., Mizuhara, H., Mizobuchi, S., Nakatsuka, H., Matsumi, M., Gofuku, A., Yokoyama, M. & Morita, K. (2010). Nonimmersive Virtual Reality Mirror Visual Feedback Therapy and Its Application for the Treatment of Complex Regional Pain Syndrome: An Open-Label Pilot Study. *Pain Medicine* 11 (pp. 622-629)
- Schmalzl, L. & Ehrsson, H. H. (2011). Experimental induction of a perceived "telescoped" limb using a full-body illusion. *Frontiers in Human Neuroscience* 5 (pp. 1-12)
- Schwoebel, J., Boronat, C. B. & Coslett, H. B. (2002). The man who executed "imagined" movements: Evidence for dissociable components of the body schema. *Brain and Cognition* 50 (pp. 1-16)
- Schwoebel, J., Buxbaum, L. J. & Coslett, H. B. (2004). Representations of the Human Body in the Production and Imitation of Complex Movements. *Cognitive neuropsychology* 21(2,3,4) (pp. 285-298)
- Schwoebel, J. & Coslett, H. B. (2005). Evidence for Multiple, Distinct Representations of the Human Body. *Journal of Cognitive Neuroscience* 17(4) (pp. 543-553)
- Seidel, S., Kasprian, G., Sycha, T. & Auff, E. (2009). Spiegeltherapie bei Phantomschmerzen: Eine systematische Übersichtarbeit. *The Middle European Journal of Medicine* 121 (pp. 440-444)
- Shiffrar, M. (2006). Body-Based Views of the World. An introduction to Body Representations. G, Knoblich, I. M. Thornton, M. Grosjean & M. Shiffrar (eds.), *Human body perception from the inside out* (pp. 135-145). Oxford: Oxford University Press
- Shumway-Cook, A. & Woollacott, M. H. (2001). Motor Control. Theory and Practical Applications (2.ed.). Philadelphia: Lippincott Williams & Wilkins (pp.1-127)

- Sirigu, A., Duhamel, J., Cohen, L., Pillon, B., Dubois, B. & Agid, Y. (1996). The Mental Representation of Hand Movements after Parietal Cortex Damage. *Science* 273(5281) (pp. 1564-1568)
- Slater, M., Perez-Marcos, D., Ehrsson, H. H. & Sanchez-Vives, M. V. (2008). Towards a digital body: the virtual arm illusion. *Frontiers in Human Neuroscience* 2 (pp. 1-8)
- Smorenburg, A., Ledebt, A., Deconinck, F. & Savelsbergh, G. (2011). Visual feedback of the non-moving limb improves active joint-position sense of the impaired limb in Spastic Hemiparetic Cerebral Palsy. *Research in Developmental Disabilities* 32 (pp. 1107-1116)
- Stone, D. H. (1993). Design a questionnaire. *British Medical Journal* 307 (pp.1264-1266)
- Sütbeyaz, S., Yavuzer, G., Sezer, N. & Koseoglu, F. (2007). Mirror Therapy Enhances Lower-Extremity Motor Recovery and Motor Functioning After Stroke: a Randomized Controlled Trial. *Archives of Physical Medicine and Rehabilitation* 88 (pp. 555-559)
- Sutter, C. & Müsseler, J. (2010). Action control while seeing mirror images of one´s own movements: Effects of perspectives of spatial compatibility. *The Quarterly Journal of Experimental Psychology* 63(9) (pp. 1757-1769)
- Takasugi, J., Matsuzawa, D., Murayama, T., Nakazawa, K., Numata, K. & Shimizu, E. (2011). Referred sensation induced by a mirror box in healthy subjects. *Psychological Research* 75 (pp. 54-60)
- Taub, E., Uswatte, G. & Pidikiti, R. (1999). Constraint-Induced Movement Therapy: A New Family of Techniques with Broad Application to Physical Rehabilitation. A Clinical Review. *Journal of Rehabilitation Research & Development* 36(3) (pp. 1-21)
- Tichelaar, V., Geertzen, J., Keizer, D. & Wilgen, P. (2007). Mirror box therapy added to cognitive behavioural therapy in three chronic complex regional pain syndrome type I patients: a pilot study. *International Journal of Rehabilitation Research* 30 (pp. 181–188)
- Touzalin-Chretien, P., Ehrler, S. & Dufour, A. (2009). Behavioral and Electrophysiological Evidence of Motor Cortex Activation Related to an Amputated Limb: A Multisensorial Approach. *Journal of Cognitive Neuroscience* 21 (11) (pp. 2207-2216)
- Touzalin-Chretien, P., Ehrler, S. & Dufour, A. (2010). Dominance of vision over Proprioception on Motor Programming: Evidence from ERP. *Cerebral Cortex* 20 (pp. 2007-2016)
- Tsakiris, M & Haggard, P. (2004). Experimenting with the acting self. *Cognitive Neuropsychology* 22(3/4) (pp. 387-407)

- Tsakiris, M & Haggard, P. (2005). The Rubber Hand Illusion Revisited: Visiotactile Integration and Self-attribution. *Journal of Experimental Psychology: Human Perception and Performance* 31(1) (pp. 80-91)
- Tsakiris, M., Longo, M. R. & Haggard, P. (2010). Having a body versus moving your body: Neural signatures of agency and body-ownership. *Neuropsychologia* 48 (pp. 2740-2749)
- Van Mier, H., Tempel, L. W., Perlmutter, J.S., Raichle, M. E. & Petersen, S. E. (1998). Changes in Brain Activity During Motor Learning Measured With PET: Effects of Hand on Performance and Practice. *Journal of Neurophysiology* 80 (pp. 2177-2199)
- Villemure, C. & Bushnell, M. C. (2002). Cognitive modulation of pain: how do attention and emotion influence pain processing? Pain 95 (pp. 195-199)
- Wall, P. D., Xu, J. & Wang, X. (2002). Human brain plasticity: an emerging view of the multiple substrates and mechanisms that causes cortical changes and related sensory dysfunction after injuries of sensory inputs from the body. *Brain Research Reviews* 39 (pp. 181-215)
- Wall, P. D. & Wolstencroft, J. H. (1977). The Presence of Ineffective Synapses and the Circumstances which Unmask Them. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 278(961) (pp. 361-372)
- Weeks, S. R. & Tsao, J.W. (2010). Incorporation of another person's limb into body image relieves phantom limb pain: A case study. *Neurocase* 16(6) (pp. 461-465)
- Wiech, K., Ploner, M. & Tracey, I. (2008). Neurocognitive aspects of pain perception. *Trends in Cognitive Science* 12(8) (pp. 306-318)
- Wilcher, D. G., Chernev, I. & Yan, K. (2011). Combined mirror visual and auditory feedback therapy for upper limb phantom pain: a case report. *Journal of Medical Case Reports* 5(41) (pp. 1-4)
- Wilson, M. (2006). Covert Imitation. How the Body Schema Acts as a Prediction Device. G, Knoblich, I. M. Thornton, M. Grosjean & M. Shiffrar (eds.), *Human body perception from the inside out* (pp. 211-228). Oxford: Oxford University Press
- Yavuzer, G., Selles, R., Sezer, N., Sütbeyaz, S., Bussmann, J. B., Köseglu, F., Atay, M. B. & Stam, H. J. (2008). Mirror Therapy Improves Hand Function in Subacute Stroke: A Randomized Controlled Trials. *Archives of Physical Medicine and Rehabilitation* 89 (pp. 393-398)

11.3 Other materials

11.3.1 Internet pages

- Pedersen, K. C. *Øvelsesprogrammer*. At: http://www.håndterapi.dk/øvelsesprogrammer.htm
- The NOI Group (2008). *Recognise*. At: http://recognise.noigroup.com/recognise.
- Walker, I. (2007). *Statistics for Psychology*. At: http://staff.bath.ac.uk/pssiw/stats2/page2/page14/page14.html.
- Urbaniak, G. C. & Plous, S. (2007). *Research Randomizer*. At: http://www.randomizer.org/about.htm

11.3.2 Videos downloaded from the internet

- Butler, D. (2009a). *Mirror Box Therapy* (7.03 minutes). Uploaded the 04.08.2009 by the Noigroup99. Downloaded from http://wn.com/Mirror_Box_Therapy_with_David_Butler the 01.05.2011
- Butler, D. (2009b). *Graded Motor Imagery* (part 1-4, 40 minutes). David Butlers presentation of Graded Motor Imagery at the March 2009 Fysioterapeuten Conference in Denmark. Uploaded the 19.06.2009 by Noigroup99. Downloaded from http://wn.com/Mirror_Box_Therapy_with_David_Butler the 01.05.2011
- Lieberman, I. (2009). *Mirror box therapy exercises* (2.45 minutes). Uploaded the 16.09.2009 by Ilan 1966. Downloaded from http://wn.com/Mirror_Box_Therapy_with_David_Butler the 01.05.2011
- Weinerberg, M. (2010). *Mirror Therapy for chronic pain* (3.28 minutes). Uploaded the 13.11.2010 by cszar. Downloaded from http://wn.com/Mirror_Box_Therapy_with_David_Butler the 01.05.2011

2066 Pages

In total 2545 pages

12.0 Appendix

12.1 "Deltagerinformation og samtykkeerklæring"

Deltagerinformation

Forsøgets titel: Spejlbehandling

Jeg vil bede dig deltage som forsøgsperson i mit forskningsprojekt. Det er frivilligt at deltage, og du kan når som helst trække dit tilsagn om deltagelse tilbage uden at skulle begrunde dette. Du vil få mundtlig information om forskningsprojektet, dets risici og fordele fra den projektansvarlige inden undersøgelsen starter, således du kan forstå, hvad det indebærer at deltage i dette projekt. Deltagelse i forsøget er anonymt og data opbevares i anonymiseret form, således at resultater ikke kan føres tilbage til dig. Du vil under ingen omstændigheder optræde i projektet med navns nævnelse. Du har ret til betænkningstid, før et evt. samtykke afgives, og du har ligeledes ret til at medbringe en bisidder, når du modtager den mundtlige information. Det vedlagte skrift "Forsøgspersonens rettigheder i et biomedicinsk forskningsprojekt" indeholder oplysninger om tavshedspligt, aktindsigt og klagegang. Hvis du beslutter dig for at deltage i forsøget, vil vi bede dig om at underskrive en samtykkeerklæring. Husk, at du har ret til betænkningstid, før du beslutter, om du vil underskrive samtykkeerklæringen.

Beskrivelse af forsøget

Hovedformålet med det indeværende forskningsprojekt er at undersøge, hvordan forskellige typer bevægelser og opgaver påvirker effekten af spejlbehandling. Spejlbehandling anvendes til smertepatienter, fx fantomsmerter, samt til genoptræning af hemiparese forårsaget af apopleksi. Behandlingen består i, at den smertefri eller "raske" side af kroppen observeres i et spejl, hvorved der for de fleste personer opstår en illusion om, at spejlbilledet er ens kropsdel. Der vil i projektet anvendes to forskellige typer spejle, hvor du vil blive bedt om at lave forskellige bevægelser samt opgaver. Før og efter hver session med spejlet bedes du tage en test, der måler evnen til håndgenkendelse, samt udfylde et spørgeskema, der undersøger den subjektive oplevelse af spejlterapien. Det forventes at nå en bedre forståelse for, hvilke mekanismer påvirker spejlterapi, samt opnå en bedre teoretisk forståelse for virkningen.

Jeg vil bede dig, at møde én gang i omkring 1 time 15 minutter, hvor du præsenteres for spejlbehandlingen, samt håndgenkendelsestesten og spørgeskemaet.

Mulige risici og eventuelle bivirkninger

Alle målinger foretages som subjektive vurderinger, og den eneste stimulation du udsættes for, er den visuelle i spejlet. For at undgå at uventede situationer opstår, kan du, hvis du ønsker det, blive ledsaget af en pårørende eller hjælper til informationssamtalen.

Inklusions- og eksklusionskriterier

Jeg ønsker at inkludere raske, højrehåndede personer mellem 18 og 80 år. Ydermere, skal du have normalt eller korrigeret syn. **Hvis du har nedsat syn, bedes du bruge kontaktlinser til eksperimentet**. Jeg ønsker ***ikke*** at inkludere personer med tidligere neurologiske, muskuloskeletale eller psykiske sygdomme eller personer med tatoveringer på hænder eller arme.

Afslutning af forsøget

Reagerer du efter forsøgslederens vurdering uventet på forsøgets procedurer, eller viser du dig på anden vis ikke egnet til videre deltagelse i forsøget, kan forsøget til ethvert tidspunkt afsluttes. Forsøget som helhed vil blive stoppet, hvis det skulle vise sig, at forsøgspersonerne generelt ikke tolererer procedurerne i forsøget eller finder forsøget for udmattende.

Forsøgslederen har ingen finansielle interesser i studiet.

Forsøget er godkendt under bi-vejleders etiske godkendelse af "Den Videnskabsetiske Komité for Region Nordjylland", sagsnummer N- 20100031.

Jeg håber, at du med denne information har fået tilstrækkeligt indblik i, hvad det vil sige at deltage i forsøget, og på den baggrund kan tage beslutningen om din eventuelle deltagelse. Jeg beder dig også om at læse det vedlagte materiale "Forsøgspersonens rettigheder i et biomedicinsk forskningsprojekt". Hvis du vil vide mere om forsøget, er du meget velkommen til at kontakte undertegnede.

Med venlig hilsen

Nana Isberg Nielsen, 10. semester psykologi AAU

Samtykke-erklæring

Det overordnede forskningsspørgsmål i indeværende projekt er:

Hvordan påvirkes effekten af spejlbehandling af forskellige typer bevægelser og opgaver udført under behandlingen?

Jeg har forstået, at jeg frit og på et hvert tidspunkt kan stille spørgsmål, der måtte falde mig ind vedrørende projektet og de metoder, der anvendes. Jeg har forstået, at jeg kan tage kontakt til Nana Nielsen på et hvilket som helst tidspunkt via e-mail adressen: nana_nilsen@hotmail.com.

Jeg har forstået, at alle data som uddrages fra spørgeskemaer, tests og observationer til brug for dette projekt, under ingen omstændigheder vil indeholde navne eller andre identificerbare karakteristika. Jeg har forstået, at min anonymitet vil blive beskyttet, og at alle informationer, jeg stiller til rådighed, vil være fortrolige. Datamaterialer fra projektet vil blive opbevaret sikkert og forsvarligt.

Min deltagelse i projektet er frivillig, og jeg har ret til – på et hvert tidspunkt – at sige nej til at deltage i projektet og stoppe min deltagelse uden nogen konsekvenser.

Jeg giver – med min underskrift – hermed samtykke til, at jeg deltager i dette projekt.

Dato **Underskrift**

12.2 Forsøgspersoners rettigheder i et biomedicinsk forskningsprojekt

Forsøgspersoners rettigheder i et biomedicinsk forskningsprojekt

Som deltager i et biomedicinsk forskningsprojekt skal du vide at:

- Din deltagelse i forskningsprojektet er helt frivillig og kan kun ske efter, at du har fået både skriftlig og mundtlig information om forskningsprojektet og underskrevet samtykkeerklæringen
- Du til enhver tid mundtligt, skriftligt eller ved anden klar tilkendegivelse kan trække dit samtykke til deltagelse tilbage og udtræde af forskningsprojektet. Såfremt du trækker dit samtykke tilbage påvirker dette ikke din ret til nuværende eller fremtidig behandling eller andre rettigheder, som du måtte have
- Du har ret til at tage et familiemedlem, en ven eller en bekendt med til informationssamtalen
- Du har ret til betænkningstid, før du underskriver samtykkeerklæringen
- Oplysninger om dine helbredsforhold, øvrige rent private forhold og andre fortrolige oplysninger om dig, som fremkommer i forbindelse med forskningsprojektet, er omfattet af tavshedspligt
- Opbevaring af oplysninger om dig, herunder oplysninger i dine blodprøver og væv, sker efter reglerne i lov om behandling af personoplysninger og sundhedsloven
- Der er mulighed for at få aktindsigt i forsøgsprotokoller efter offentlighedslovens bestemmelser. Det vil sige, at du kan få adgang til at se alle papirer vedrørende din deltagelse i forsøget, bortset fra de dele, som indeholder forretningshemmeligheder eller fortrolige oplysninger om andre
- Der er mulighed for at klage og få erstatning efter reglerne i lov om klage- og erstatningsadgang inden for sundhedsvæsenet

(Dette tillæg udgives af Den Centrale Videnskabsetiske komité og kan vedhæftes den skriftlige information om det biomedicinske forskningsprojekt. Spørgsmål til et projekt skal rettes til den regionale komité, som har godkendt projektet)

12.3 Questionnaire - mirror

Nummer______________ Køn____________ Alder_________________

De følgende udsagn beskriver den oplevelse nogle mennesker får, når de kigger i spejlet i forbindelse med spejbehandlingen. Ud fra en skala fra 1 til 7, hvor 1 er helt ***uenig*** *og 7 er helt* ***enig****, skal du angive hvor enig du er med udsagnet.*

- **Det føltes, som om jeg kiggede direkte på min hånd og ikke på et spejlbillede**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Jeg følte ikke, at jeg havde kontrol over hånden i spejlet**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Det føltes, som om hånden i spejlet tilhørte mig**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Når jeg flyttede på genstande, følte jeg ikke, at jeg havde fuld kontrol over dem**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Jeg følte, at det var mig, der lavede de bevægelser hånden i spejlet foretog**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Den venstre hånd i spejlet var ikke min**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Jeg følte ikke, hånden i spejlet bevægede sig, som jeg forventede**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Føltes det som din venstre eller din højre hånd, du kiggede på i spejlet?**

Ikke som venstre						Meget som venstre
1	2	3	4	5	6	7
Ikke som højre						Meget som højre

1 2 3 4 5 6 7

- **Det føltes, som om jeg frit kunne bevæge mine hænder, som jeg havde lyst til**
  Helt Uenig — Helt Enig
  1 2 3 4 5 6 7

- **Hånden i spejlet bevægede sig, som jeg forventede**
  Helt Uenig — Helt Enig
  1 2 3 4 5 6 7

- **Det føltes, som om hånden jeg kiggede på var min hånd**
  Helt Uenig — Helt Enig
  1 2 3 4 5 6 7

- **Jeg havde en følelse af, at min venstre hånd blev større**
  Helt Uenig — Helt Enig
  1 2 3 4 5 6 7

- **Jeg havde en følelse af, at min højre hånd blev større**
  Helt Uenig — Helt Enig
  1 2 3 4 5 6 7

- **Det føltes, som om jeg havde fuld kontrol over hånden i spejlet**
  Helt Uenig — Helt Enig
  1 2 3 4 5 6 7
  På intet Tidspunkt — Hele Tiden
  1 2 3 4 5 6 7

- **Det føltes, som om hånden i spejlet var en anden persons hånd**
  Helt Uenig — Helt Enig
  1 2 3 4 5 6 7

12.4 Questionnaire – without mirror

Nummer:_______________Køn:____________________ Alder:_________________

De følgende udsagn beskriver den oplevelse nogle mennesker får, når de kigger i spejlet i forbindelse med spejbehandlingen. Ud fra en skala fra 1 til 7, hvor 1 er helt ***uenig*** *og 7 er helt* ***enig****, skal du angive hvor enig du er med udsagnet.*

- **Det føltes, som om jeg kiggede direkte på min hånd og ikke på et spejlbillede**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Jeg følte ikke, at jeg havde kontrol over min hånd**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Det føltes, som om den venstre hånd tilhørte mig**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Når jeg flyttede på genstande, følte jeg ikke, at jeg havde fuld kontrol over dem**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Jeg følte, at det var mig, der lavede de bevægelser den venstre hånd foretog**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Den venstre hånd var ikke min hånd**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Jeg følte ikke, min hånd bevægede sig, som jeg forventede**

Helt Uenig						Helt Enig
1	2	3	4	5	6	7

- **Føltes det som din venstre eller din højre hånd, du kiggede på?**

Ikke som venstre						Meget som venstre
1	2	3	4	5	6	7
Ikke som højre						Meget som højre

1 2 3 4 5 6 7

- **Det føltes, som om jeg frit kunne bevæge mine hænder, som jeg havde lyst til**
  Helt Uenig ... Helt Enig
  1 2 3 4 5 6 7

- **Den venstre hånd bevægede sig, som jeg forventede**
  Helt Uenig ... Helt Enig
  1 2 3 4 5 6 7

- **Det føltes, som om hånden jeg kiggede på var min hånd**
  Helt Uenig ... Helt Enig
  1 2 3 4 5 6 7

- **Jeg havde en følelse af, at min venstre hånd blev større**
  Helt Uenig ... Helt Enig
  1 2 3 4 5 6 7

- **Jeg havde en følelse af, at min højre hånd blev større**
  Helt Uenig ... Helt Enig
  1 2 3 4 5 6 7

- **Det føltes, som om jeg havde fuld kontrol over min hånd**
  Helt Uenig ... Helt Enig
  1 2 3 4 5 6 7
  På intet Tidspunkt ... Hele Tiden
  1 2 3 4 5 6 7

- **Det føltes, som om hånden var en anden persons hånd**
  Helt Uenig ... Helt Enig
  1 2 3 4 5 6 7

12.5 Appendix – Results

12.5.1 Correlation analysis of AC and RT scores

12.5.2 Correlation analysis of ownership ratings and RT

12.5.3 Correlation analysis of agency ratings and RT

12.5.4 Ownership groups and RT: Independent t-test

12.5.5 Agency groups and RT: Independent t-test