Using the Brain to Help Rehabilitate the Body
Factors which can Affect Injury Rehabilitation Outcome

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I hereby certify that all material in this final year project which is not my own work has been identified and that no work is included for which a degree has already been conferred on me.

Signature: ___________________________________________
Abstract

Physical activity can be beneficial to both physical and mental health, but can also lead to injuries. While injury rehabilitation through physical therapy is mostly focused on physical exercise, there are also other factors, which may influence rehabilitation outcome. The factors reviewed are: rehabilitation adherence, mindfulness meditation, mental imagery, action observation, self-talk, goal-setting and social support. This essay investigates the neural correlates of these factors, as well as how they can affect rehabilitation outcome and well-being, to a lesser degree, during rehabilitation. Among the effects found are performance enhancement, increased self-efficacy, increased pain tolerance, increased motivation and reduced strength loss. Suggestions for future research is also provided.

Keywords: Physical activity, injury rehabilitation, imagery, mindfulness meditation, neuroscience
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Introduction

According to the World Health Organization (WHO), physical inactivity is the fourth largest risk factor (6%) for global mortality, following high blood pressure, tobacco and high blood glucose. Physical inactivity has great implications for the prevalence of diseases such as cardiovascular disease, cancer and diabetes. WHO therefore recommends at least 150 minutes of moderate-intensity aerobic physical activity, or 75 minutes of vigorous-intensity activity, each week to reduce the risk of these diseases, depression, and to improve cardiorespiratory and muscular fitness. In addition there are recommendations for muscle-strengthening exercises of major muscle groups at least two times each week (WHO, 2010). With large drawbacks where physical activity is absent, there may be a number of benefits where it is present. A brief review of the benefits of physical activity, on physical and mental health, will be presented to shed some light on this.

Where there is physical activity there is; however, always the risk of physical injury, which can be a hindrance in everyday life, and act as a stressor. A physical injury in this case will be defined as an injury that will benefit from rehabilitation, and will hinder normal exercise routines, and possibly other everyday activities, for a longer period of time. The benefits of physical activity, on both physical and mental health, might be lost to some extent during the period of rehabilitation, due to inability to engage in regular physical activity. To return to normal functioning after an injury, rehabilitation through physical therapy is often used.

Rehabilitation professionals are highly proficient in prescribing physical exercises to help restore function after an injury. There are a number of psychological factors that relate to rehabilitation adherence, which are important for an efficacious rehabilitation programme to be successful. Some of these factors may also have a direct impact on rehabilitation outcome,
as well as a positive impact on well-being during rehabilitation, by limiting some of the negative consequences injury might have on well-being, due to psychological responses, and the potential loss of the benefits of physical activity. Furthermore, it is likely that each factor correlates with a different neural response.

Heaney, Walker, Green and Rostron (2014) suggest that sports injury rehabilitation professionals benefit from having an understanding of the psychological impact of injury and how psychological factors can influence the rehabilitation process. Some areas where training, for rehabilitation professionals, is often recommended are positive self-talk, imagery, goal-setting and relaxation. How these concepts affect rehabilitation will be investigated together with how the concepts can affect the brain.

All this leads to the following question: Which psychological factors can influence rehabilitation outcome, and how do these factors affect the brain? The aim of this work is; therefore, to investigate what effects, if any, psychological processes have on the outcome of injury rehabilitation, and the neural activation of these processes where available. Before investigating these processes and neural mechanisms, a brief overview of the psychological impact of injury will be presented. This will be followed by factors that may have a positive impact on rehabilitation outcome. In the concluding discussion, the research on the different areas already covered will be summarized regarding rehabilitation outcome, neural representation and also, to a lesser extent, the impact on well-being. The well-being aspect will be in relation to the benefits of physical activity, which may be lost during rehabilitation. Research is however lacking in several areas, and suggestions to remedy this lack of research will be provided.
Benefits of physical activity and exercise

The WHO defines physical activity as “any bodily movement produced by skeletal muscles that requires energy expenditure”, and physical exercise as “a subcategory of physical activity that is planned, structured, repetitive, and purposeful in the sense that the improvement or maintenance of one or more components of physical fitness is the objective” (WHO, 2010, p. 52-53).

Physical health benefits

It is quite evident that physical activity can lead to increased physical fitness, and it has been found that this fitness relates to a more positive health perception (Gerber et al., 2010). With at least moderate-intensity physical activity, most days of the week, there is a reduction of 30% to all cause mortality, compared to sedentary individuals. Most of this reduction in mortality is due to increased cardiorespiratory fitness. Physical activity also contributes to reduced risk of cancer, and the relationship between the two was found to be strongest for colon cancer and breast cancer (Bauman, 2004). The risks for chronic metabolic and cardiorespiratory diseases are reduced for regular exercisers, partly because exercise has anti-inflammatory effects. Furthermore there is evidence that exercise, combined with diet, can be beneficial in prevention of type 2 diabetes mellitus, in high-risk individuals (Gleeson et al., 2011).

Mental health benefits

The relationship between physical activity and mental health seems more complex than the relationship between physical activity and physical health. A cross-sectional population-based study, with 19288 participants, conducted by De Moor, Beem, Stubbe, Boomsma, and De Geus (2006), found that exercisers are less anxious, depressed, and
neurotic, but more extroverted, than non-exercisers. These differences were consistent over both gender and age. It has been suggested that high extroversion and low neuroticism are two personality traits that are closely related to subjective well-being, and therefore important for mental health (Hayes & Joseph, 2002).

Apart from exercisers showing fewer symptoms of depression than non-exercisers, it has been shown that exercise has antidepressant effects, at least in those suffering from major depressive disorder. These effects seem to outlast the period of exercise, as the antidepressant effect has been shown several months after the termination of the exercise program. It has been hypothesized that the antidepressant effects of exercise can be linked to hippocampal neurogenesis. Decreased hippocampal volume has been found in individuals suffering from major depressive disorder (Ernst, Olson, Pinel, Lam & Christie, 2006) and physical exercise interventions have been reported to increase grey matter in hippocampus, as well as in frontal areas. Decreased hippocampal volume can also occur due to ageing, but aerobic exercise seems to counteract these effects as well, resulting in reduced risk of dementia, and preservation of cognitive functioning. N-acetylaspartate, only found in neuronal tissue, is important for increasing neuronal energy production, and has been seen as a marker for neuronal health, viability, and number. A positive correlation between cardiovascular fitness and levels of N-acetylaspartate has been found in older adults (Hötting & Röder, 2013).

There are a number of different molecules that are released, when engaging in exercise, which may be involved in the increased neurogenesis. Studies have shown that exercise increases levels of β-endorphins, which are a class of opiate peptides, serotonin, and vascular endothelial growth factor, a protein which stimulates the formation of blood vessels, which all may influence neurogenesis. Brain-derived neurotrophic factor has also been shown to be increased following exercise, and this may influence neuronal regeneration and survival (Ernst et al., 2006). Other neurotransmitter systems are also affected by exercise, as levels of
noradrenaline and acetylcholine increase, cortical uptake of choline is enhanced, and dopamine receptor density increases. (Hötting & Röder, 2013).

While most studies are conducted using aerobic exercise, Taspinar, Aslan, Agbuga, and Taspinar (2014), took a different approach when using hatha yoga and resistance exercise, also called power-weight training, as interventions in a pilot study. Compared to a control group, both types of exercise decreased depression symptoms and fatigue, increased quality of life and self-esteem, and improved body image. There were; however, some differences between the interventions, with Hatha yoga showing greater improvement for fatigue, self-esteem and quality of life, and resistance exercise showing greater improvement of body image.

Stress

Stress, both positive and negative, is a part of everyday life, and has many effects on both the brain and the body. The stress response can cause release of neurotransmitters, such as noradrenaline and serotonin, peptides, and steroid hormones, such as glucocorticoids including cortisol. The response to an acute stressor is usually followed by a quick return to baseline levels. Chronic stress can; however, cause alterations in neuronal structure, expression of particular genes and neuronal firing patterns (Joëls & Baram, 2009). The glucocorticoids, which are secreted by the endocrine system as a response to stress, affect various aspects of the body such as cardiovascular activation, inflammatory and immune responses, metabolism, and reproduction. Several brain functions are also affected, such as cerebral glucose transportation and utilization, appetite, and memory (Sapolsky, Romero & Munck, 2000).

The effects of stress are neither inherently good nor bad. Memory is one example of this, where stress can enhance consolidation, but impair retrieval (Schwabe, Joëls,
Roozendaal, Wolf & Oitzl (2011). There are; however, a variety of negative effects associated with chronic stress, such as neuronal loss and decreased neurogenesis in the hippocampus, impaired cognitive performance, and increased risk for depression (Marin et al., 2011). Higher stress exposure also correlates with more negative self-evaluation of health, more suffering from somatic and psychological complaints, and more absentness from work (Gerber, Kellman, Hartman & Pühse, 2010).

When a physical injury is perceived as a stressor it can impact the recovery, since converging research show that wound healing is impaired by psychological stress (Gouin & Kiecolt-Glaser, 2011). Stress is highly individual and cognitive appraisal, how an individual interprets a stressor, affects whether a stressor is perceived as an opportunity or as a threat, which in turn influences what effects a stressor has (Aztalos et al., 2012).

*The impact of physical activity on stress*

Stress, and coping with stress, can have large effects on both mental health and quality of life. (Aztalos et al., 2012). One study by Gerber and colleagues (2010) showed that, while stress did not seem to correlate negatively with exercise, it seemed as if exercise and perceived fitness can act as buffers between stress and health, with exercise being the better buffer. Those with high perceived stress, who exercised more, expressed less somatic and psychological complaints, and were less absent from work, than those engaged in less exercise. Moderate-intensity exercise proved to be a better buffer than vigorous exercise, although vigorous exercise was associated with higher general health satisfaction and psychological well-being (Gerber et al., 2010).

Moderate-intensity physical activity can also reduce the short term physiological effects of stress on, for instance blood pressure and muscle tension, and help people recover from brief psycho-social stressors. It is likely that this is because physical activity leads to
more effective coping mechanisms, as active people have shown reduced reactivity to, as well as faster recovery times from, stressors, and less illness when experiencing negative life events, as well as being less susceptible to life stress, compared to those less active. Physical activity also increases self-esteem and self-efficacy, and may also lead to feelings of mastery and competence, which in turn may lead to a less threatening cognitive appraisal of a stressor. This has been seen in sport participants, who show less perceived stress and distress than those not participating in any sport, regardless of what kind of sport (Aztalos et al., 2012).

As noted earlier there is always the risk of injury when being engaged in any form of physical activity. An injury can be a source of negative life stress, and a hindrance to many forms of physical activity, which in turn may reduce the some of the benefits which come from physical activity. There are; however, competent physical therapists, who can be of assistance when an injury occurs, by facilitating a speedy recovery through physical rehabilitation. A rehabilitation programme often includes physical exercises, designed to strengthen the injured areas. Successful rehabilitation can enable return to pre-injury levels of functioning, but can also facilitate post injury growth, through skills, both physical and psychological, acquired during rehabilitation.

Psychological responses to injury

Cognitive appraisal of an event decides the emotional and behavioural response, and can be broken down into primary appraisal, whether an event is harmful to the individual, and secondary appraisal, how the individual is able to handle the consequences of the event. This suggests that the emotional and psychological response to an injury are based on the perception of the injury, and that the injury itself is less important, than how the injury is perceived. One study found that coping skills and social support correlate with lower levels of mood disturbances after an injury (Green & Weinberg, 2001). Malinauskas (2010) also
found that a larger amount of perceived stress, measured by the Perceived Stress Scale-10 (PSS-10), was associated with diminished life satisfaction, measured by the Satisfaction with Life Scale (SWLS). Results also showed that participants with a major injury, more than 21 days of loss of sports participation, experienced greater stress and less life satisfaction, than those with minor injuries.

It has been shown that while the emotional state after an injury is generally negative, diagnosis and treatment, through physical therapy, have an impact on both the positive and negative emotional response, by increasing the former and decreasing the latter (Dawes & Roach, 1997). Johnston and Caroll (2000) also found that anger, anxiety, confusion, depression and fatigue decrease, while energy increases, as rehabilitation progresses. The psychological skills needed to lessen the impact of the injury, through cognitive appraisal, may not always be present at the time of injury. There might also be other factors that can influence well-being during rehabilitation, as well as the outcome of the rehabilitation process.

A review by Brewer (2010) analysed 26 correlational studies and found positive correlations between rehabilitation outcome and, among others, self-efficacy, and the use of goal-setting and imagery. There is; however, the problem of not being able to draw conclusions regarding causality in correlational studies, but there are also some experimental studies. Before looking at the evidence on how some of these topics can influence rehabilitation outcome, the effects of adherence to a rehabilitation programme will be investigated.
Factors which may affect rehabilitation outcome

Adherence to rehabilitation

It seems likely that adherence to a recommended efficacious rehabilitation programme would have a positive effect on rehabilitation outcome. Lyngcoln, Taylor, Pizzari and Baskus (2005) investigated this link in patients recovering from a distal radius fracture, a broken wrist. All participants had scheduled appointments with a physical therapist, and in addition they were presented with exercises to perform at home. Adherence was measured by a home exercise diary, attendance of scheduled therapy appointments, and the Sports Injury Rehabilitation Attendance Scale (SIRAS). After six weeks of rehabilitation a significant positive relationship was found between adherence and outcome, and 50% of the variance in outcome could be predicted with the adherence to home exercises. Although adherence has a positive relationship with rehabilitation outcome in general, this is not true for all aspects of rehabilitation. Brewer et al. (2000) found that rehabilitation adherence after anterior cruciate ligament reconstruction, measured in roughly the same way as Lyngcoln et al. (2005), was positively correlated to only one of three outcome aspects. This was functional ability, measured by the distance the patient was able to hop on one leg. Subjective symptoms, such as instability, pain, limping etcetera, as well as ligament laxity were unaffected by adherence (Brewer et al., 2000). Other studies on rehabilitation, following anterior cruciate ligament reconstruction, reach similar conclusions, when it comes to the effect of adherence on rehabilitation outcome. A review of studies on adherence, following anterior cruciate ligament reconstruction, shows that increased adherence was associated with better outcome, but also with increased ligament laxity, and that the age of the participants influenced whether the adherence was associated positively or negatively with outcome (Mendonza, Patel & Bassett, 2007).
There are several psychological and social factors that correlate with adherence, such as social support, pain tolerance, self-motivation, the interpretation of scheduling concerns, belief in the efficacy of the treatment and coping. Findings also indicate that mood disturbance is inversely correlated to adherence and that these mood disturbances correlate with negative appraisal of the injuries (Spetch & Kolt, 2001). The type of rehabilitation setting also seems to have an impact on which factors influence adherence. Goal-setting was a predictor of adherence in both home exercises and clinic treatment, whereas positive self-talk only predicted adherence to home exercise. Both goal-setting and positive self-talk are ways to take personal control over rehabilitation. Goal-setting is a way to stay focused, and self-talk is a way to stay motivated. The source of motivation for adherence rehabilitation also seems to differ between different age groups, with higher self-motivation leading to greater adherence in older participants, but those with greater athletic identity in younger participants have the greater adherence (Mendoza et al. 2007).

Studies on several different models, trying to describe different variables influencing adherence, have have shed some light on some factors that may influence adherence. Adherence has been shown to be highest when patients see the health threat of the injury as severe, believe the rehabilitation programme to be effective, and see themselves as capable of completing the programme. Self-motivated patients are less influenced by outside factors, which may have a negative effect on adherence, and those receiving social support are more likely to adhere to a rehabilitation programme. Mood disturbance was inversely correlated with adherence, but social support was positively related to adherence. The ability to handle pain can also influence adherence, as pain tolerance is positively correlated to adherence. (Christakou & Lavelle, 2009).

There seems to be quite a few factors that may influence adherence to rehabilitation, for instance social support, pain tolerance, goal-setting, imagery, self-efficacy and self-talk.
Social support

Social support is the exchange of resources, between at least two individuals, which is perceived to enhance the well-being of the individual receiving the support. There is a positive relationship between social support and adherence to injury rehabilitation, and by using support groups, or pairing of injured athletes, social support can be enhanced in a rehabilitation setting (Spetch & Kolt, 2001). Social support can also be encouraging to health behaviours in general, such as exercising and consumption of fruit and vegetables. Lack of social support can be a hindrance to both health behaviours and adherence, as well as increasing the risk for mortality (Reblin & Uchino, 2008). In addition to influencing adherence, social support may also enhance well-being, by reducing distress and fear of re-injury, and increasing self-confidence, self-efficacy and motivation (Rees, Mitchell, Evans & Hardy, 2010).

Rees and associates (2010) investigated the correlational relationship between social support and the psychological responses to injury. The social support of 261 injured athletes, was assessed by using the Social Support Inventory for Injured Athletes (SSIIA). Stressors were also assessed, by asking to what extent the two items, incapacitation and slowness of progress, were an issue, as well as the psychological responses, by using the Psychological Responses to Sport Injury Inventory (PRSII). It was hypothesized that stressors from injury would be associated with negative psychological responses, and that social support would have a buffering effect on these responses, as well as being associated with positive psychological responses. The study consisted of two groups, a high-performance standard
group, with 147 participants of national or international standard, and a low-performance group, consisting of 114 participants of college, recreational or local league standard. There were a wide range of injuries in the groups, but no significant difference in injury severity between the groups. The study was conducted using self report measures of social support, stressors and psychological responses, before each of the 10 appointments with a physical therapist. Stressors were related to negative psychological responses in both groups, but there was a difference in the effect of social support between the groups. In the high-performance group there was a main effect, with social support being directly associated with lower levels of negative psychological responses. In the low-performance group there was a buffering effect. This means that social support was associated with lower levels of negative psychological responses when the participants experienced high levels of negative psychological responses, but social support was relatively unimportant when the amount of stressors was low.

When studying 123 injured university athletes, Malinauskas (2010) found that social support, measured by the Multidimensional Scale of Perceived Social Support, together with perceived stress, measured by the PSS-10, can predict 43% of the variance in life satisfaction, measured by the SWLS. Social support had a buffering effect on how perceived stress affected satisfaction with life (Malinauskas, 2010). Similar buffering effects have been seen in other studies, where social support has reduced the effect of stressors, on both cardiovascular reactivity and cortisol responses. The effect of having a supportive companion present during painful stimulation has also been investigated, and results show reduced self-reported pain unpleasantness (Eisenberger, 2013), and, as noted earlier, pain tolerance correlates with adherence (Spetch & Kolt, 2001).

Although a lot is known about the effects of social support on psychological responses, research on the neural correlates of these effects is somewhat scarce. It does seem
likely that social support affects neural areas, possibly by activating safety-related areas and inhibiting threat-related areas, and there are a few studies which provide support for this. Ventromedial prefrontal cortex (VMPFC) is part of a larger neural circuit, associated with reward processing, and has been seen to be activated during relative absence of threat or stress. Both VMPFC and posterior cingulate cortex (PCC) has been seen to respond to cues that signal safety, as well as during conditions of low amounts of pain or stress. Activation in these two areas has also be shown to correlate negatively with cardiovascular, cortisol and threat-related responses. Regions that have been found to be involved in detecting and responding to threat and danger include the dorsal anterior cingulate cortex (dACC), anterior insula (AI) and amygdala. The amygdala responds to threatening stimuli and controls the expression of threat-related changes in the sympathetic nervous system and the endocrine response. AI and dACC are known for their involvement in pain processing, but have also shown greater activation in response to approaching threatening stimuli (Eisenberger, 2013).

Studies have shown that viewing pictures of relationship partners, while experiencing pain, can lead to participants reporting pain to a lesser degree, than when viewing pictures of strangers or mere acquaintances. The activity in VMPFC as well as the PCC was increased in the participants, when viewing their partners, and the activity in the dACC, AI and posterior insula was decreased. In addition, greater perceived support from the partner was associated with greater activity in the VMPFC, and greater pain relief was associated with decreased activity in the dACC and AI. Social support has also been shown to have an effect on the stress of social exclusion. Less distress was reported when an attachment figure was imagined to be present, and there was less activation in the hypothalamus, a region which has been implicated in stress-related responding. During social exclusion emotional support also showed increased activity in the dACC and PCC, and decreased activity in the insula (Eisenberger, 2013).
As noted earlier, goal-setting is positively related to rehabilitation adherence (Brewer, 2010). Goal-setting can be used to increase motivation to strive towards a goal, by influencing the degree of effort, the focus and direction of attention, and enhance persistence. In a sport setting, goal-setting has been used to increase self-efficacy, as well as to enhance performance and perceptions of success. Goal-setting can create positive expectations for rehabilitation, which in turn can create motivation and enhance adherence (Christakou & Lavelle, 2009). As long as the goals are within the limits of the ability to reach them, more challenging goals lead to better performance, compared to only doing your best. Goal-setting can also reduce variation in performance, by reducing the ambiguity of what the purpose of an action is, (Locke & Latham, 2002).

Goals direct attention and effort towards goal-relevant activities, and increase and prolong effort. The relationship between goals and performance is strongest with goal commitment, especially when the goals are difficult. This commitment is facilitated by the importance of reaching the goal, and self-efficacy, the belief that the goal can be reached. Commitment can be enhanced by making the goal public, and by being part of the goal-setting process, to make the goal intrinsic (Locke & Latham, 2002).

Self-efficacy can be increased by being part of the goal-setting process, by setting an intrinsic goal. Motivation can be enhanced with the use of goal-setting, by creating discrepancies between the current situation, and the desired future situation (Locke & Latham, 2002). Performance satisfaction can also be influenced by goal-setting, as goals set the standard for self-satisfaction. Feedback is; however, required to monitor the progress towards the goal, as progress and goal importance, are strong predictors of feelings of success and well-being (Locke & Latham, 2006). Goal-setting and planning are skills that can be learned, which have a positive causal relationship with well-being (MacLeod, Coates &
It also seems as if goal-setting is related to faster healing as Ievleva and Orlick (1991) found correlations between recovery time and the use of goal-setting.

Theodorakis, Maliou, Papaioannou, Beneca and Filactakidou (1996) investigated the short-term effects of personal goals, self-efficacy, and self-satisfaction, on injury rehabilitation. Three groups, with 92 female participants in total, were studied. The first experimental group consisted of 32 participants, who had undergone arthroscopic surgery for the knee during the last six months, and suffered from muscle weakness of the quadriceps femoris muscle, due to inhibition of muscle activity. The other two groups were healthy females, with 29 in the experimental group and 30 in the control group. Using a isokinetic dynamometer, which measures the performance of muscles groups, knee extension was measured in four trials, each consisting of 10 repetitions. The mean scores of the first two trials were used as a measure of ability. After the first two trials, the participants in the two experimental groups were informed of their performance, completed self-efficacy expectations, the strength and magnitude of their self-expectations of the trial, self-satisfactions scales, how satisfied they would be to achieve a certain performance, as well as setting a goal for the next trial. This procedure was repeated after the third trial. The members of the control group were instructed to do their best, and did not complete any scales, nor did they receive any feedback (Theodorakis et al., 1996).

The results showed significant performance improvement for both experimental groups, suggesting the importance of goal-setting in injury rehabilitation programs. The control group; on the other hand, had reduced performance under the condition of doing their best. Self-satisfaction and self-efficacy, for the experimental groups, correlated with the increase in performance, indicating that those with higher confidence and satisfaction set higher goals and performed better. This suggests that goal-setting can be beneficial to performance. The data also indicated that performance affected goal-setting and self-efficacy,
and that ability, the mean score of the first two trials, was the strongest indicator of performance. Neither self-efficacy, nor satisfaction, had any effect on performance or personal goals. In the case of self-efficacy, this lack of effect was explained with ability having such high effects. It was therefore suggested that personal goal-setting, combined with other strategies which increase self-efficacy, may help athletes decrease recovery time (Theodorakis et al., 1996).

Theodorakis, Beneca, Malliou and Goudas (1997) conducted a similar study of the effects of goal-setting on performance, anxiety, self-efficacy and self-satisfaction, during a knee rehabilitation program. The program lasted four weeks, and consisted of 37 participants who had undergone arthroscopic surgery recently, and were recommended quadriceps strengthening exercises, with 20 in the experimental group and 17 in the control group. There were three training sessions each week using a isokinetic dynamometer. Prior to each strengthening exercise the members of experimental group were informed of their performance of the respective exercise during the last session, and then wrote down the goal for each exercise in the current session. The control group did not set any goals, nor did they receive any feedback. Performance was measured four times during the experiment, before the first and after the fourth, eighth and twelfth session. The measurement from the first test served as a measure for ability. At the same time as the performance test, questionnaires were completed for self-efficacy, by asking how certain the participant was of achieving a certain level of performance, anxiety, by using the Mental Readiness Form, and self-satisfaction with performance, by asking how satisfied the participants would be to achieve a certain level of performance. The two groups did not differ in ability, self-efficacy, anxiety or satisfaction at the beginning of the experiment. The difference in performance increase between the two groups were significant, with the experimental group having the greater increase. There were; however, no significant differences in self-efficacy or anxiety between the groups. Self-
satisfaction for the experimental group actually decreased, which was explained by setting higher goals and thereby raising the standards used for evaluating performance.

**Self-talk**

It has already been said that self-talk can predict some forms of rehabilitation adherence (Mendoza et al. 2007), and that sports injury rehabilitation professionals are recommended to be trained in positive self-talk (Heaney et al. 2014). As with many other concepts, there is no simple universal definition of self-talk, which can sometimes prove to be problematic. Hardy (2006) discusses the concept of self-talk thoroughly and considers it to be a multidimensional concept comprised of statements that are either overtly, said out loud, or covertly, as an inner voice, addressed to oneself. There is also valence, a bi-polar component to the content of self-talk, where self-talk is either encouraging, positive self-talk, or criticizing, negative self-talk. The research on positive versus negative self-talk is somewhat inconclusive in predicting performance, but it seems as if performance can influence which type of self-talk is used, by for instance using negative self-talk to express dissatisfaction with performance.

Another component is the origin of the self-talk, whether it is self-determined by the individual or chosen by an outsider, such as a coach or experimenter. There might be a difference in how self-talk generates motivation in this aspect, as the self-talk chosen by the individual should have positive effects on intrinsic motivation, according to Edward L. Deci and Richard M. Ryan's cognitive evaluation theory. In short, this theory states that self-determination for an individual's actions is related to their perception of choice (Hardy, 2006).

The interpretation of whether self-talk is motivating or de-motivating can vary from situation to situation. Even negative self-talk can have a positive effect on motivation, when
interpreted the right way. Self-talk can be divided in two broad categories depending on function, motivational and instructional. The instructional category consists of skill and strategy functions, and the motivational category of arousal, drive and mastery functions. Finally there is the frequency of self-talk, where it has been found that successful athletes may use more self-talk than unsuccessful ones. Research shows that more self-talk is not necessarily better, in fact some forms of self-talk, especially instructional, may lead to decreased performance (Hardy, 2006).

Senay, Albarracin and Noguchi (2010) suggest that the linguistic structure of self-talk can influence the likelihood to form intentions of a certain behaviour. The use of interrogative talk, instead of declarative, may lead to increased intrinsic motivation. The interrogative form can be used in behaviour-change counselling, persuasive messages and behavioural requests, to facilitate changes in behaviours, attitudes and perceptions. Self-posed questions may lead to increased autonomy and intrinsic motivation in goal pursuit, and greater chance to execute a behaviour, for instance physical therapy.

Senay and co-workers (2010) conducted a series of four experiments to test the effects of self-talk on behaviour and intentions. The first two experiments studied the behaviour, and in the first study 53 participants were asked to solve anagrams, after being told to think either that they would work on anagrams, or asking themselves whether they would work on anagrams. The results showed that those who asked themselves whether they would work on anagrams solved significantly more anagrams. The second study, with 50 students, also studied anagram solving, but instead of being told what to think they there primed in a writing task, where they wrote one of the following 20 times: “Will I”, “I will”, “I” or “Will”. Those who wrote “Will I” solved significantly more anagrams than the other three groups, between which there was no significant difference in performance.

The last two experiments studied intentions, and in the third test 46 participants were
primed, in a similar fashion to the second experiment, but only writing “I Will” or “Will I” this time. Before the priming they were asked to write down a patterned or random sequence of 24 numbers to clear their mind. After the priming they were asked to write down which physical activities they had planned for the next week, and how many hours they would devote to the activity. Those primed with a patterned sequence of numbers prior to the “Will I”-condition had stronger intentions to exercise, compared to those in the “I Will”-condition, but no such interaction was found with those primed by a random sequence. This suggests that it is necessary to view the order of words as meaningful for the priming to take effect (Senay et al., 2010).

The final experiment used 56 participants, who were primed by writing only “I Will” or “Will I”. They were then asked, on a scale from 1 to 7, with 7 being the highest, how likely they were to start, or continue, to exercise regularly. This was followed by the question of, again on a scale from 1 to 7, how well 12 reasons applied to their motivation to exercise. Half of the reasons dealt with intrinsic motivation, and the other half with extrinsic. The “Will I”-condition scored significantly higher on intention to exercise and intrinsic motivation, but not on extrinsic. This suggests that using the interrogative form, either voluntarily or by priming, can affect behaviour and intention (Senay et al., 2010).

Cumming, Nordin, Hortin and Reynolds (2006) found that the valence of self-talk, combined with imagery, affected performance of a dart-throwing task, but not self-efficacy. The study consisted of 95 participants in five groups, one control group and one group for each combination of facilitative or debilitative imagery and self-talk, one group with both factors facilitative, one with both factors debilitative and two with one factor facilitative and the other debilitative. Three trials were conducted, one baseline trial and two experimental trials. Those in the facilitative self-talk and facilitative imagery group performed significantly better than the other groups in both experimental trials. The facilitative self-talk and
debilitative imagery group only had a significant improvement between trial 1 and 2, and the
debilitative self-talk and debilitative imagery group actually showed a significant decrease in
performance in both trials. Finally the debilitative self-talk and facilitative imagery group and
the control group showed no difference between the trials (Cumming et al., 2006). Araki et al.
(2006) came to a similar conclusion in their experiment on the importance of the belief in
self-talk. They found that the valence of self-talk was more important than the belief in self-
talk. A group using only positive self-talk performed better on a balance task, compared to a
group using only negative self-talk, or a mix of positive and negative self-talk.

When studying the difference in the effects of motivational and instructional self-talk
on performance of a sit-up task, Hardy, Hall, Gibbs and Greenslade (2005) found that self-
talk was positively related to self-efficacy, whereas Cumming and colleagues (2006) found no
such relationship in a study mentioned earlier. There were however a few complications in
the study which made it impossible to study the difference between motivational and
instructional self-talk, since all groups used both motivational and instructional self-talk.
They did; however, find that self-talk was moderately and positively associated with self-
efficacy, which was measured by asking how confident the participants were in their ability to
carry out the task, and to do well on the task. Valence and direction, whether the self-talk was
motivating or de-motivating, were the two aspects of self-talk that were studied. There was a
positive relationship between both aspects and self-efficacy, but valance showed a stronger
relationship. Higher self-efficacy, but not self-talk valence or direction, was associated with
better performance. (Hardy et al., 2005).

Hatzigeorgiadis, Zourbanos, Mpoumpaki and Theodorakis (2009) studied 72 tennis
players, to investigate the effects of self-talk on task performance, anxiety, somatic and
cognitive, and self-confidence, in a task involving tennis drives. Self confidence and anxiety
was measured by the Competitive State Anxiety Inventory-2 revised (CSAI-2R). Steps were
taken to increase anxiety, by introducing incentives for performance. Two groups were used, one experimental group, receiving self-talk instructions, and a control group, not receiving any self-talk instructions. There were; however, several participants who were excluded from the study. Those in the control group who already used self-talk on a regular basis, and a few participants in the experimental group who did not use self-talk, despite being instructed to do so, were the ones excluded. The results of the study further consolidates the idea that self-talk can increase task performance, but also showed a significant difference in the two groups, in regard to increased self-confidence and reduced cognitive anxiety in the experimental group. There was also a non-significant decrease in somatic anxiety. The increase in performance was correlated with the increase in self-confidence, but no correlations were found between performance and somatic or cognitive anxiety.

Much of the research done on self-talk has not been directly associated with rehabilitation, even though balance tasks are often used in rehabilitation of lower limb injuries, as studied by Araki and colleagues (2006). Theodorakis, Beneca, Goudas, Antoniou and Malliou (1998) investigated the effects of the of self-talk on performance and anxiety, measured by the Mental Readiness Form, during a quadriceps strengthening program, often used for rehabilitation of knee injuries. The 30 participants, all of whom had arthroscopic knee surgery within six weeks before the study, were divided into an experimental group, with 16 participants, and a control group, with 14 participants. Both groups completed three quadriceps training sessions a week for two weeks, with the difference being that the experimental group was instructed to repeat, covertly or overtly, positive messages, presented to them on a computer screen, during training. Results showed a significant difference between the groups on performance, with the experimental group having the better performance, but not on anxiety.

In may appear as if self-talk is just a psychological phenomenon, but there are a few
studies that have investigated the neural regions involved in self-talk. The two regions that are most often associated with regulating overt speech, Broca's area, in the left frontal cortex, and Wernicke's area, in the posterior superior temporal cortex, are also involved in covert self-talk. Wernicke's area processes acoustic information, which is sent, via a large bundle of nerves called the arcuate fasciculus, to Broca's area, responsible for the generation of speech. In 96% of all individuals, articulated speech in controlled by the left hemisphere. Regarding self-talk Broca's area seems to generate self-talk, and lateral temporal regions bilaterally, including Wernicke's area, seem to monitor self-talk (Gibson & Foster, 2007).

In an fMRI study, Brühl, Rufer, Kaffenberger, Baur and Herwig (2014) used self-talk to determine the neural circuits associated with self-appraisal, both positive and negative. The 30 participants were instructed to use short statements, to make themselves aware of either positive or negative aspects of themselves. Following each round of statements, the participants viewed 1 of 12 neutral pictures of themselves, taken by the experimenters prior to the fMRI session. Each picture was used 3 times, one for a neutral condition, and one for each valence of self-talk, for a total of 36 viewings. The order of the pictures and the valence conditions were randomized. During both negative and positive self-talk, dorsomedial prefrontal cortex (DMPFC) and left dorsolateral prefrontal cortex (DLPFC) had higher activation, compared to the neutral condition. These areas have been associated with self-reference and self-reflection. Positive self-talk was associated with higher activation of the left amygdala, ventral striatum, the anterior cingulate cortex (ACC) and left temporal cortex, compared to negative self-talk, while negative self-talk showed greater activation of the occipital brain regions. Positive self-talk had no influence on the perception of photos, but negative self-talk activated parietal and insular brain regions. This lack of influence could be due to a pre-existing positive bias towards oneself being present in the participants.

The amygdala has been suggested to be involved in emotional arousal and stronger
activation of the amygdala in the study could indicate more emotional arousal. The ventral striatum has been associated with positive stimuli and reward anticipation or prediction and reward delivery, as well as anticipation of aversive stimuli. Some studies have also shown the ventral striatum to be involved in anticipation of aversive stimuli, such as pain or disgust. The negative self-talk activated regions that have been associated with rumination, such as the insula, DLPFC, DMPFC and occipital regions. The DLPFC has also been regarded to be involved in negative, and even depressive, cognitions, in self-regulation and in emotional regulation (Brühl et al., 2014).

*Mental motor imagery*

Mental imagery is the process to represent information in our minds, without external sensory input. This can be used to mentally practice skills or movements, when used systematically, and can also be used in interventions to help develop psychological skills (Moran, 2009).

During motor imagery, the mental execution of a movement without actual overt movement, the premotor cortex and supplementary motor area are activated. When imagining movement using the fingers, toes and tongue, the same brain areas, as when actual movement is executed, were activated. The activity in the premotor cortex was correlated with how vivid the imagery is. The parietal cortex also seems to be involved in motor imagery, as single-pulse TMS deactivating neurons in this area seems to decrease the accuracy of imagery. It is also suggested that neuronal activity in the primary motor cortex, M1, is involved in motor learning that comes from imagery practice, but when it comes to the matter of activation in M1 there are discrepancies between different studies. Imagery can be useful to acquire motor skills and enhance strength and joint flexibility as well as improving sports performance (Mizuguchi, Nakata, Uchida & Kanosue, 2012).
Motor imagery can also affect the functional organization of the brain. In one pioneering study, Pascual-Leone et al. (1995) showed that imagery alone can cause the same plastic change in motor areas, as the actual execution of a piano playing finger exercise, albeit to a somewhat lesser degree. The same was true for performance, when executing the finger exercise, but after a relatively short training session, two hours, the performance of both the imagery group and the execution group were at a similar level.

Many studies on how imagery affects rehabilitation have been conducted with neurological patients, who suffered from stroke or some other brain damage, see Munzert, Lorey and Zentgraf (2009) for a review. Christakou, Zervas and Lavallee (2007) took a different approach and studied 20 athletes suffering from grade II ankle sprain, a sprain with partial ligament tear. All participants took part in the same physical therapy treatment for four weeks, 60 minutes of therapy three times a week. In addition, the experimental group, with 10 participants, engaged in 45 minutes of imagery practice, following each therapy session. The imagery consisted of the exercises used during the preceding physiotherapy session. All participants were already familiar with imagery techniques from their sports participations, but during the first four imagery sessions there were additional imagery training. The study showed no significant difference between the two groups in functional stability, leg-hops and walking down a staircase, or dynamic balance, which was tested on a balance platform. There was; however, a significant difference between the two groups in muscular endurance, toe- and heel-rises, suggesting that imagery can have a positive effect on the functional rehabilitation.

Stenekes, Geertzen, Nicolai, De Jong and Mulder (2009) have also studied imagery in non-neurological patients. Their subjects were recovering from flexor tendon surgery of the hand, a procedure which is followed by several weeks of relative immobilization, since the tendon strength is decreased post surgery. During this immobilization a functional
reorganization of the brain seems to occur, inducing temporary loss of efficient cerebral control of hand movement. This loss of cerebral control was characterized by increased cortical demand and reduced striatal involvement (de Jong et al., 2003). As the healing progresses, the load on the tendons can gradually be increased. The experiment group were instructed to perform eight sessions of imagery a day, where they imagined flexion and extension movements of the hand. All other aspects of the recovery process were the same for both groups. The only significant difference was that the experimental group had less increase in preparation time, compared to the control group. Preparation time was measured using button pressing, and was regarded as an indicator of the central control processes. An increase in preparation time shows slower information processing, and less efficient control of hand movements. This suggest that motor imagery training can help reduce impairment of central control during immobilization, at least, in information processing (Stenekes et al., 2009).

There are other injuries that can require immobilization during the healing process, such as arm or leg fractures. One of the complications due to this immobilization is a decrease in the ability to maximally activate muscles. This loss of strength occurs primarily during the first week, and is thought to be the result of central neuromotor adaptations that decrease the ability to voluntarily activate the muscles. To test whether it is possible to limit the central neuromotor adaptation using imagery, Newsom, Knight and Balnave (2003) conducted an experiment. The 17 participants had their non-dominant forearm immobilized with a cast during 10 days. The imagery group was instructed to imagine squeezing a rubber ball, without activating their muscles, whereas the control group did not receive any imagery instructions. Grip strength, as well as wrist-flexion and -extension strength, was measured before and after immobilization. Immobilization did not cause any significant loss of grip strength in either groups, even though the imagery group showed less decrease in grip
strength. There was however a significant decrease in wrist-flexion and -extension strength in the control group, but no significant decrease in the imagery group. This suggests that imagery can be a tool to prevent loss of strength during immobilization.

One of the more serious injuries, which frequently occurs during sporting activities, is a torn anterior cruciate ligament (ACL). In many cases reconstructive surgery of the ACL is required, and during the early stages of recovery muscle activation is reduced. Lebon, Guillot and Collet (2012) studied the effects of imagery on pain, using The Visual Analog Scale (VAS), muscle activation, using electromyography, functional recovery and range of movement in twelve individuals recovering from reconstructive surgery of the ACL. Both the control group and imagery group received traditional rehabilitation, but the imagery group also received motor imagery training. The imagery was instructed to be kinesthetic, instead of just visual, where the participants imagined the sensation of muscle contractions, and joint tension, of a full knee extension. Both groups showed improvement in muscular activation, but there was a significant difference between the two groups, with the imagery group showing the greater improvement. No other significant differences were found. With no significant difference between the groups in decreased muscle atrophy, it was suggested that imagery enhances motor reconstruction only in the neural pathways, and not in the muscles.

Action observation of motor skills

An injury can also prevent the actual movement needed for skill execution, which can prevent acquiring, maintaining and enhancing skills. Pascual-Leone et al. (1995) showed that motor imagery can be used as an alternative to skill execution to acquire new skills. Action observation, observing the actions of others, is another strategy for skill acquisition, that is believed to share some neural mechanisms with motor imagery. One study compared the two strategies, when learning the complex motor task of moving the right hand and foot in an
angular direction, while moving the left hand and foot in opposite angular direction, at a frequency of 1 herz. Results showed that action observation can be more effective than imagery, when learning a complex motor task in a single training session (Gatti et al., 2013).

Lorey et al. (2013) used fMRI to determine which brain areas were activated during execution, observation and imagery of motor actions. The motor actions studied were flexion and extension of either the fingers, toes or both, on the right side of the body, in 18 right-handed and right-footed participants. These three motor actions, combined with either imagery, execution or observation, added up to 9 different conditions. In addition there was a counting task, serving as a control condition. FMRI results showed activation in the following areas; M1 in both hemispheres, for execution and imagery, but only left M1 for observation, supplementary motor cortex in both hemispheres, for execution and imagery, inferior frontal gyrus and superior and inferior parietal cortex in both hemispheres for all three, ventral and dorsal premotor cortex bilaterally, for execution and imagery, but only in the right hemisphere for observation, and finally the intraparietal sulcus in both hemispheres for imagery, but only in the left hemisphere for execution, and in the right hemisphere for observation. The study also investigated whether the movement was mapped somatotopically within the motor cortices, and found that a somatotopical map existed in the left motor cortex and premotor cortex, for execution and imagery, but not for observation, even though these areas were activated during observation. This suggests that there is some form of functional equivalence between action execution, motor imagery and action observation. With activation of the same brain areas, action observation might have the same effects as motor imagery.

Porro, Facchin, Fusi, Dri and Fadiga (2007) conducted a study, consisting of three experiments, where the effects of action observation were investigated. In all three experiments there was a movement group, using a rubber band as resistance when pulling the right index finger away from the middle finger, and an action observation group, where each
member observed a member from the movement group executing the rubber band exercise. Daily training sessions, consisting of 25 repetitions, were conducted six times over a period of two weeks. In addition, the first two experiments had a control group and the third had an imagery group, where the members imagined the same movement as the movement group executed, instead of a control group.

The first experiment, with 9 members in each group, measured the isotonic force between the index and middle finger, before and after the intervention, of both the right and left hand. The results showed increased isotonic strength, in both the movement and observation group, post-training compared to pre-training, for both hands, but there was no change in the control group. Because of bilateral change, it was suggested that the improvement was a result of change in motor control circuits resulting in more efficient use of spinal motor units. The second experiment, with 10 participants in the control group and 9 in the experimental groups, measured isometric force, using the second digit, the index finger, and fifth digit, the little finger, on both hands. Results showed an increase in force in both the movement group and observation group, post-training compared to pre-training, for the right index finger only. The final experiment, with 9 participants in each group, used TMS to map the cortical areas activated, both during rest and during the assigned exercise, and electrodes to measure motor-evoked potentials. This experiment showed no significant difference between pre- and post-training measurements. There was however an increase in motor-evoked potential between the resting state and execution of the assigned exercise. This increase was largest in the movement group, followed by the imagery group and the increase was smallest in the observation group (Porro et al., 2007).

Other benefits of imagery and action observation

Imagery can also have other benefits during rehabilitation. In a cross sectional study
Law, Driediger, Hall and Forwell (2012) investigated the effect of imagery on perceived pain, overall limb functioning, and satisfaction with injury rehabilitation. This was done using the Athletic Injury Imagery Questionnaire-2 (AIIQ-2), to assess the function of imagery, VAS, to measure pain perception, and the Lower Extremity Functional Scale (LEFS), to assess the overall functioning. They divided 83 athletes, suffering from lower limb injury, into two groups, depending on whether the athlete used pain imagery or not. The groups did not differ in the amount of pain experienced or the level of lower limb functioning, but the imagery group were more satisfied with their rehabilitation and their imagery use in other areas, cognitive, motivational and healing imagery, was greater.

Callow, Hardy and Hall (2001) were one of the first to experimentally study how motivational general-mastery imagery, imaging staying focused when confronted by problems, can be used to increase self-efficacy, in a study involving four junior badminton players. The players were studied during 24 weeks, and started a three week imagery intervention at different points, after 5, 7, 9 or 11 matches. The intervention started with a session of imagery training, designed to increase imagery ability. During the three weeks following this training, five more guided imagery session were conducted, where the participants were given imagery scripts to used in their individual daily imagery session. Results showed that the self-efficacy of three of the four players increased, although only two of them showed a significant increase. The fourth player experienced large fluctuations in self-efficacy before the intervention and a significant decrease afterwards. However, self-efficacy in the forth player was more stable after the intervention and started to increase at the end of the 24 weeks. It was suggested that this delayed increase could be due to the fact that the player started playing in a higher division with better players, or a delayed effect of the intervention. It was therefore suggested that mastery imagery may be used to enhance self-efficacy.
Jones, Bray, Mace, MacRae and Stockbridge (2002) investigated the effects of motivational general-mastery imagery, imaging coping and mastery of challenging situations, and motivational general-arousal imagery, imaging emotions to control arousal and anxiety, on perceived stress, measured using the Perceived Stress Index (PSI), and self-efficacy in a climbing task. Self-efficacy was measured by asking the participants how confident they were with using the techniques they learned to climb well, and how confident they were with climbing to the best of their ability. The participants, 33 females with no previous climbing experience, took part in one hour climbing exercises on a climbing wall on four consecutive weeks. Participants were assigned to a control group, engaging in light aerobic exercise and stretching, in addition to climb training, and an imagery group. The imagery group received a script detailing a successful climb up the wall, which included both motivational-general mastery and motivational general-arousal imagery, which was used during each climbing session. A trait anxiety test, the Trait Anxiety Scale, was taken before the very first climb, a perceived stress test, using one word to rate stress at a certain point in time, was used at four different points during the final climb, and a self-efficacy test was taken before the final climb. Results showed significant results for perceived stress, with the imagery group showing less stress. The imagery group also showed higher results on both aspects of self-efficacy, but only the confidence in technique was significant, even though confidence in ability was close to being significant, with p = 0.08. This suggests that motivational general-mastery and motivational general-arousal imagery can be used together used to manage emotions and, at least partially, to increase self-efficacy.

Motivation may also be influenced by action observation, as shown by Oliveira, Araújo and Abreu (2013). Sixty physically active participants were randomly divided into two groups; an action observation group and a control group. Both groups were tested on cognitive and motor performance, as well as proneness to exercise, measured by VAS, before
and after watching a video. The video the action observation group watched contained human motor action, in the form of a compilation of scenes from movies with physical exercise, sports and fight content. The control group watched a compilation containing much less implied human motor action. There was a significant difference in proneness to physical exercise between the groups, as the proneness of the action observation group increased, whereas it decreased in the control group. There was also a significant difference in in performance of the cognitive task, with the action observation group having the better performance, but there was no difference in the motor performance task.

Mindfulness meditation

Mindfulness, and the practice of mindfulness meditation, have received considerable attention lately, and have been shown to have a number of benefits. Mindfulness is the awareness and non-judgemental acceptance of the current experience at any given moment. Mindfulness correlates with positively with higher levels of positive affect, life satisfaction, vitality, and with lower levels of negative affect and fewer psychological symptoms. The magnitude of these benefits are also correlated with the extent of meditation practice (Keng, Smoski & Robins, 2011).

Studies have consistently shown that meditation, not necessarily mindfulness meditation, is associated with differences in brain structure, when comparing both long-term practitioners and novices with non-practitioners. Areas that have been identified in several independent studies are the rostrolateral prefrontal cortex, anterior/mid-cingulate cortex, orbitofrontal cortex (OFC), insular cortex, somatomotor cortices, inferior temporal gyrus, fusiform gyrus, hippocampus, corpus callosum and superior longitudinal fasciculus. It also seems as if brief meditation training, 5 to 60 hours of practice, can cause changes in brain structure, in both grey matter areas and white matter tracts. The grey matter areas, that have
been identified, include anterior and posterior cingulate cortices, insular cortex, temporoparietal junction, hippocampus, caudate nucleus, and cerebellum. The white matter tracts, that have been identified, include corpus callosum, superior longitudinal fasciculus, sagittal stratum, thalamic radiation, and corona radiata. All these areas, except for the caudate nucleus, thalamic radiation, and corona radiata, have been identified as having similar differences in long-term meditation practitioners. There is; however, limited evidence of meditation being the causative factor of these differences (Fox et al., 2014).

In-depth details of the functionality, of several of the areas mentioned above, are beyond the scope of this essay, but some are relevant. The anterior- and mid-cingulate cortices have been implicated in self-regulation and self-control, and have been seen to be activated during pain, reward processing, and conflict monitoring. The OFC is connected to the primary sensory regions, as well as the limbic system, and is critical in determining the relationship between stimuli and motivational outcomes. In addition, the OFC is implicated in emotional regulation, especially in reappraising and down-regulating negative emotional states. Improved self-monitoring and better regulation of negative emotions are consistent with the beneficial effects of meditation on depression, anxiety and stress (Fox et al., 2014).

Atrophy of the hippocampus is associated with clinical disorders involving stress, anxiety and depression. Structural changes in the hippocampus might be due to meditation's potential amelioration of such conditions and reduction of stress (Fox et al., 2014). As mentioned earlier, stress can decrease neurogenesis in the hippocampus (Marin et al., 2011). The primary and secondary somatosensory cortices process tactile information, such as pain, conscious proprioception and touch (Fox et al., 2014). This can be of interest in a rehabilitation setting as pain tolerance correlates with adherence (Spetch & Kolt, 2001).

Jon Kabat-Zinn (1982) was a pioneer in investigating the influence of mindfulness meditation on pain in chronic pain patients. By using a 10-week programme, where
participants were taught mindfulness meditation for two hours once a week, and then proceeded to practice meditation at home, perception of pain was significantly reduced in the majority of patients suffering from chronic pain. Most of the reduction was also maintained in several follow-ups, in the months following the programme. The pain in this study was measured by using the McGill-Melzak Pain Rating Index, a Body Parts Problems Assessment scale, a Dermatone Pain Map and a Table of Levels of Interference (Kabat-Zinn, 1982).

This programme was the precursor to mindfulness-based stress reduction (MBSR), an 8 to 10 week programme that uses mindfulness meditation to teach individuals how to relate to their psychological and physical conditions in a more accepting and non-judgemental way. MBSR has been shown have a number of beneficial effects, such as lower levels of depression, anxiety, psychological distress and perceived stress, as well as higher levels of satisfaction with life, quality of life, positive affect and self-compassion (Keng et al. 2011). The areas where MBSR interventions have been tested are very varied, including chronic pain, fibromyalgia, cancer, depression, anxiety disorders and, as the name implies, stress, in different settings such as medical school and prison. The results show that mindfulness training might enhance coping with distress and disability, in both serious disorders, as well as everyday life. The benefits are not limited to psychological health, as physical health has been shown to be improved in medical symptoms, physical impairment and sensory pain (Grossman, Niemann, Schmidt & Walach, 2004).

There is also evidence that mindfulness and mindfulness meditation may affect pain tolerance in experimentally induced pain, using interventions that are shorter in duration than MBSR. Kingston, Chadwick, Meron and Skinner (2007) studied the effects of a three week mindfulness intervention on pain tolerance in a cold pressor test, where the hand is submerged into cold water. Pain was measured by the total submersion time, and an self-report of how painful the experience was, on a scale from 1 to 10. The mindfulness group
showed significant differences between a pre and post intervention test, in both decreased pain intensity, and increased hand submersion time, but the control group showed no differences.

Zeidan, Gordon, Merchant and Goolkasian (2010) shortened the duration of the mindfulness intervention even more, when using a three day intervention to study the effects of mindfulness meditation on electrically induced pain. A series of three different experiments, using the same test procedure, was conducted. In each experiment there were two test sessions, one at the start of day one and one at the end of day three. At the start of each test session three pain levels were determined; the level where the sensation is first detected, called cutaneous threshold, and a high and low pain level. The first experiment showed that a three day mindfulness meditation intervention, teaching different mindfulness meditation skills on three consecutive days, decreased anxiety significantly as well as increasing mindfulness skills. Additionally, state anxiety was reduced following each mindfulness meditation session. There was also a significant decrease in response to pain, after a 13 minute meditation session on the final day. The decrease in pain response in the high pain condition was correlated with the increase in mindfulness skills, but the low pain condition showed no such correlation. One unexpected result was that the threshold levels for stimulus intensity, in the high and low pain levels, increased between the sessions.

The second experiment used different cognitive manipulations, math distraction and relaxation, to see if these would have the same effect on pain as the meditation did. Participants were tested on day 1 and 3, just as in the first experiment, but the participants did not receive any mindfulness meditation training. In the math distraction condition participants counted down from 1000 with decrements of 7, as fast and accurate as possible. The results showed a significant decrease in pain response for math distraction only in the high pain condition, and no decrease for relaxation. In this experiment there were no increases in the
levels of stimulus intensity (Zeidan et al., 2010).

The final experiment compared the effects of math distraction, mindfulness meditation and relaxation, using the same procedure as in the first experiments. All participants received the same mindfulness meditation training as in the first experiment. This experiment replicated the results from the previous experiments by showing that meditation reduced pain response in both high and low levels, math distraction only on the high and relaxation did not affect the pain response at all. The decrease in the high level of pain was greater for meditation, compared to math distraction. In addition, the increases in mindfulness and levels of stimulus intensity, as well as the decrease in anxiety, from the first experiment were replicated (Zeidan et al., 2010).

Zeidan and associates (2012) reviewed studies on the effects of meditation on pain, in an attempt to find common neural correlates leading to the modulation of pain. Two studies on the trait effects of meditation, meaning that the meditators were not engaged in meditation during the measurements, that came to different conclusions were reviewed. The first study found that a group of meditators were less sensitive to pain, during baseline, compared to a control group, whereas the second study found no such difference. The second found that meditation-related pain relief was associated with a difference in the anticipation of pain, but the first study found no such difference. The first study also found that meditators showed increased activation, using fMRI, in pain-related cortices, such as the mid-cingulate cortex, insula, secondary somatosensory cortex and thalamus, but the second study found decreased activation, using EEG, in the insula and secondary somatosensory cortex. Increases in activation were found in the second study in cognitive and emotion-related areas, such as the ACC and ventromedial prefrontal cortex, and the first study found decreases in dorsolateral prefrontal cortex, medial prefrontal cortex, orbitofrontal cortex, amygdala and hippocampus. Worth noting is that some aspects, other than measurement methods, differed, such as
There are also some studies on the neural correlates of the state effects of meditation on pain, with the meditators engaging in meditation during measurements. Zeidan and associates (2011) investigated the underlying brain mechanisms of the modulation of pain, during mindfulness meditation, after a 4 day mindfulness meditation training intervention. Both pain unpleasantness and pain intensity were decreased during meditation, compared to rest. FMRI showed reduced pain-related afferent processing in primary somatosensory cortex, but the changes were not correlated with pain intensity or unpleasantness. Decreases in pain intensity was; however, associated with activation in ACC and right anterior insula, and activation in the OFC was associated with decreases in pain unpleasantness.

Increased activation in the contralateral secondary somatosensory cortex and the posterior insula has also been shown to correlate negatively with pain unpleasantness, during meditation. Both these areas are implicated in pain processing. Activation was also found, during pain anticipation, in the rostral anterior cingulate cortex and the ventromedial prefrontal cortex, just as in one study on trait effects above. These regions are involved in the cognitive and emotional control of pain anticipation (Zeidan et al., 2012).

Discussion

Exercise, injury and adherence

It is quite evident that physical inactivity can have a big negative impact on well-being, as it is the fourth largest risk factor for global mortality (WHO, 2010). The opposite is also true, with physical activity having a number of benefits on both physical and mental health, as previously noted. Engaging in physical activity does not only affect the body, as research has shown that physical activity can also affect the brain, which in turn might
influence mental health. One area identified as being affected by physical activity is the hippocampus, where an increase in grey matter has been found after physical exercise interventions. This increase is possibly due to increased neurogenesis, as exercise can lead to the release of several substances, which have been associated with neurogenesis, such as β-endorphins, serotonin, vascular endothelial growth factor, and brain-derived neurotrophic factor. Decreased hippocampal volume can be the result of suffering from a major depressive disorder, chronic stress, or ageing. It is therefore plausible that exercise induced neurogenesis can counteract some of the effects resulting from decreased hippocampal volume. In fact, exercise has been found to have anti-depressant effects, as well as reducing the risk of age related dementia and preserving cognitive functioning, which can be impaired due to ageing.

Unfortunately, accidents do happen, and injuries during physical activity are common. Injuries can lead to more sedentary behaviour which in turn can mean that the benefits of physical activity are reduced or lost. Added stress, from negative cognitive appraisal of the injury, can also cause negative psychological effects and impaired healing (Gouin & Kiecolt-Glaser, 2011). As previously noted some of the effects of chronic stress is the exact opposite of the benefits of physical activity, such as neuronal loss, decreased hippocampal neurogenesis and increased risk for depression. Physical activity acts as a buffer to stress, by limiting the effects of stress on health, and can affect cognitive appraisal of a stressor, by increasing self-esteem and self-efficacy. To limit the repercussions of an injury, both on physical and mental health, a speedy recovery is important and this is where physical therapists and injury rehabilitation programmes come in.

Factors which may affect rehabilitation outcome

The question posed earlier was: Which psychological factors can influence rehabilitation outcome, and how do these factors affect the brain? A number of factors
affecting outcome directly or indirectly, have been found, as have the underlying neural mechanisms, for some of these factors.

It seems intuitive that adherence, also called compliance in some literature, to an efficacious rehabilitation programme will affect the outcome of the programme positively. While there is a great deal of evidence supporting that adherence is positively related to rehabilitation outcome in general, it is not necessarily true for all aspects of rehabilitation. As previously noted, some studies show that a few outcome aspects are negatively influenced by rehabilitation adherence. While adherence to muscular strengthening exercises undoubtedly increases muscle strength, other areas, such as wound healing, might be influenced negatively to some degree through the same exercises, due to increased strain on the injured area. Despite some aspects of some rehabilitation programmes showing a negative correlation with adherence, the rehabilitation programmes will be treated as efficacious and adherence will be considered to positively influence the rehabilitation outcome.

There is a positive relationship between social support and adherence, and a negative relationship between social support and the effects of stressors. These effects include negative psychological effects, as well as cardiovascular reactivity and cortisol responses. In addition, social support affects pain tolerance, which in turn may affect adherence. The research on how social support affects the brain seems to be scarce. There is; however, some evidence that social support increases activity in safety-related brain areas, such as the VMPFC and PCC, and decreases activity in dACC, and both the posterior and anterior insula. Greater decrease in activity in the dACC and AI was associated with greater pain relief.

Goal-setting can affect many psychological aspects, such as motivation, persistence, and effort, which may be reasons for goal-setting being positively related to adherence. In addition it can increase performance in rehabilitation related tasks, which in turn may positively affect rehabilitation outcome, and reduce recovery time. There seems to be a lack
of studies specifically investigating the neural correlates of goal-setting. There are some studies dealing with the neural networks involved in goal-directed behaviour and choice, attention, planning, executive function, and related areas, that could possibly have been included. I did; however, not feel this would shed much light on the neural correlates of goal-setting, or fit in the scope of this essay, as an entire essay could be devoted to this. Also worth mentioning is that much of the behavioural research on goal-setting have been conducted in business-related settings. Because of this, all results are not necessarily transferable to a rehabilitation setting, but clearly goal-setting can influence rehabilitation positively.

In addition to predicting rehabilitation adherence, self-talk can affect performance positively, as well as increasing self-confidence and possibly reducing anxiety. Unsurprisingly, covert self-talk activates the same regions, Broca's and Wernicke's area, as ordinary speech, with Broca's area generating self-talk and Wernicke's area monitoring self-talk. During positive self-talk, areas such as the amygdala, associated with emotional arousal, and ventral striatum, associated with reward and positive stimuli, as well as anticipation of aversive stimuli, were activated. Negative self-talk activated regions associated with rumination, such as the insula and occipital regions. With only one study found on the differences in neural activation, between positive and negative self-talk, no conclusions can be conclusively drawn, other than self-talk being associated with activation of neural regions.

Mental motor imagery and action observation have a lot in common. Both practices can increase performance, and be used for skill acquisition, but there are also similarities in neural activation. Similar, but not identical, activation of both imagery and action observation has been shown in M1, inferior parietal cortex, superior and inferior parietal cortex, ventral and dorsal premotor cortex, and the intraparietal sulcus. The same areas were activated during the execution, of the same movements that were imagined or observed, suggesting that there is some functional equivalence between execution, imagery and action observation, when it
comes to neural activation. In a rehabilitation setting this equivalence can be used to practice movements, through imagery or observation, which cannot be executed, due to immobilization or other injury related problems. When movements cannot be executed, for an extended period of time, a functional reorganization seems to occur, due to the plasticity of the brain. By using action observation or imagery, the effects of such a reorganization can be reduced, as studies have shown. The same reasoning can be applied to motor skill maintenance and acquisition. In addition, imagery may increase satisfaction with rehabilitation, and increase emotional control, and action observation may increase motivation.

The practice of meditation has been shown to have several beneficial effects, such as lower levels of depression, anxiety, psychological distress and perceived stress, as well as higher levels of positive affect and quality of life. Meditation has been associated with differences in a number of brain areas. Among these areas are the anterior- and mid-cingulate cortices, that have been seen to be activated during pain, reward processing and self-control, and the OFC, which in implicated in emotional regulation, and in determining the relationship between stimuli and motivational outcomes. These areas might be involved in the beneficial effects of meditation on depression, anxiety and stress. Another area showing increased grey matter is the hippocampus, and as noted earlier hippocampal degeneration is associated with depression and chronic stress.

In the context of rehabilitation, the positive effects of mindfulness meditation on pain tolerance can be of importance, since pain tolerance correlates with rehabilitation adherence. Difference in activation in several pain-related areas, such as the mid-cingulate cortex, insula, thalamus and secondary somatosensory cortex, as well as cognitive and emotion-related areas, such as the ACC, VMPFC, DLPFC, OFC and hippocampus, have been seen in meditators, not engaged in meditation, during experimentally induced pain, but not in
controls. During meditation activation in ACC and AI, has been associated with decreased pain intensity, and activation in the OFC, secondary somatosensory cortex, and posterior insula has been associated with decreased pain unpleasantness. There have however only been a few studies conducted on the neural response meditation has on pain tolerance, and some results are conflicting, thus the only conclusion that can be drawn, regarding the neural correlates of mindfulness meditation on pain, is that meditation seems to influence areas related to pain and emotion.

**Effects on well-being**

Many of the concepts covered here a positive effect on well-being during rehabilitation, which should limit the negative effect of injury on well-being. Social support can lessen the effects of stress, by having a buffering effect, and increase self-efficacy. Both coping, which can be increased through mindfulness meditation, and social support are associated with lesser mood disturbances following injury. Goal-setting can increase self-efficacy, self-satisfaction, and lead to faster healing. Cognitive anxiety can be lowered by using self-talk. Imagery use can increase both rehabilitation satisfaction and self-efficacy, as well as lead to better emotional control. Action observation can increase proneness to exercise, by watching videos with physical activity content. Finally mindfulness meditation, used in MSBR, can lead to lower levels of depression, anxiety and perceived stress, as well as higher levels of quality of life and positive affect. Most of these positive effects are already familiar to the observant reader as they can also be the result of physical activity.

To further limit the negative impact on injury, due to inability to engage in normal physical activity, it could be beneficial for injured individuals to pursue alternative forms of physical activity where possible. In addition, those engaging in team sports could benefit from attending practice only to observe, when unable to participate due to injury, by using
action observation to maintain existing, or acquire new, skills.

Suggestions for future research

In general, all areas covered could use more research on the underlying neural correlates, as brain imaging studies are scarce in several of them, especially in the context of rehabilitation. The research on the neural correlates of social support and self-talk are very recent, which might mean that there is an increased interest in the topic, and that more studies will be conducted soon. Another interesting approach would be the neural differences between declarative and interrogative forms of self-talk, since behavioural differences have been found. Goal-setting is especially an area where brain imaging studies could prove to be beneficial, as no studies have been conducted on the difference in neural activation of goal setting. This could be done in a similar manner to the studies where the difference in performance, between the use of goal-setting and just doing your best, were measured.

While there are many studies conducted on the neural correlates of imagery and action observation, when it comes to motor movement, there is still a lack of studies on other aspects of the topics, such as motivation, emotion regulation and self-efficacy. Meditation also needs more research on the neural correlates, as it is uncertain whether meditation is the sole cause of the changes in brain structure that have been found. Regarding the effects of meditation on the modulation of pain-tolerance, there is conflicting evidence, as well as only a few studies. More studies in this area could possibly result in converging evidence in the future. In addition, research on meditation interventions in a rehabilitation setting, on pain-tolerance and emotional regulation, could be beneficial.

The study of the effects of dyad training, training in pairs, in a rehabilitation setting could be beneficial. By using dyads, there is a possibility of utilizing the benefits from both action observation and social support in a cheap and effective way. Action observation could
prove to affect motivation, self-efficacy and skill acquisition, by seeing someone else perform the same exercises. The added benefit would be social support, which might limit the effects of injury-related stress as well as increasing pain tolerance, and reducing the negative emotional response to injury.

There are also many studies conducted on a single injury type, such as ACL tears. While this approach has its benefits, research on different types of injuries in the same study can be beneficial. This increases the possibility of recruiting more participants, as well as being able to more easily generalize the results to different types of injuries. While this is not possible in all settings, it could be useful in, for instance, studying the neural effects of imagery on a number of different injuries requiring immobilization.

Development of efficacious interventions, based on neuroscientific and behavioural research, and integrating them into physical rehabilitation programmes, is also recommended. Some of these interventions can be cheap, easy to administer and potentially effective, such as using guided meditation, imagery scripts, group training to add social support to rehabilitation, or instructions for using self-talk in more effective way.
References


practitioners. *Neuroscience & Biobehavioral Reviews, 43*, 48-73. doi:10.1016/j.neubiorev.2014.03.016


doi:10.7600/jpfsm.1.103


effect of personal goal, self-efficacy, and self-satisfaction on injury rehabilitation.

*Journal of Sport Rehabilitation, 5*(3), 173-183.


