Needs & wants in rehabilitation therapy for a myoelectric prosthesis after an arm-hand amputation

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SUMMARY

OBJECTIVE

Limb loss is a potentially devastating event in a person's life, often resulting in profound physical, psychological and vocational consequences. After amputation the patient can choose to wear a myoelectric prosthesis. To be able to use the prosthetic in the right way, the patient will rehabilitate and train with the prosthetic guided by the physiotherapist and occupational therapist. The goal of this research is to identify attributes which result in high effectiveness of the rehabilitation therapy for a myoelectric prosthesis according to the patients and the health care professionals.

METHODS

Data was collected in multiple stages. To find out what is known from the literature regarding attributes which result in high effectiveness of the rehabilitation and successful use of the myoelectric upper limb prosthesis a systematic literature search is done.

To identify attributes besides the ones found in literature which can influence successful rehabilitation interviews were done with health care professionals. To structure the attributes found in literature and interviews the UTAUT model was used.

At the end of the interview a list of attributes which were found in literature were shown to the interviewees. On a rating scale from no influence at all to very large influence the interviewees scored the characteristics to identify the importance of the attributes which were found in literature.

To identify the importance of the found attributes according to the patients an online questionnaire using the Analytic Hierarchy Process (AHP), a multi criteria decision analysis technique developed by Saaty, was used.

RESULTS

Patients and health care professionals agree that the expectations the patients have of the myoelectric prosthesis have the largest influence on the effectiveness of the rehabilitation therapy, and that the facilitating conditions are least important.

The patients and health care professionals have different opinions about some of the other attributes.

Where the health care professionals ranked the factors concerning the effort expectancy of the training as having a low influence on the success of the rehabilitation, the patients ranked this category as important. There is agreement between the patients and health care professionals that the patients' expectations and insight in the training are more important than the time and difficulty of the training.

A remarkable difference between the answers of the patients and health care professionals is concerning the importance of the patient's influence on the decision for the prosthesis type. The health care professionals scored this relative low, where the patients ranked this as quite important for a successful rehabilitation.

The health care professionals scored that follow-up after the rehabilitation program has a large influence on successful rehabilitation where the patients gave this factor a very low relative importance.

Concerning Social influences on the effectiveness of the rehabilitation there is a large disagreement between the patients and health care professionals. Where the health care professionals feel that the influence of the social environment is quite important on the successful rehabilitation, the patient ranked this category as the least important.

The interviews with health care professionals resulted in some new attributes which weren't found in literature, which were part of the patient questionnaire. Three of those factors are ranked as having al large influence on the success of the rehabilitation by the patients:

- Offering the patients the opportunity to try different prosthetic options before choosing a prosthesis type
- Regular measurements of the patients' progress during the rehabilitation
- Focusing the rehabilitation on a patient's occupation

RECOMMENDATIONS

Health care professionals need to make sure the patient has the right expectations before the decision for a prosthesis type is made.

- Give the patients accurate and realistic information in an early stage to prevent the patients from constructing wrong expectations.
- Offering the patient the option of trying different options before making a decision can make sure the patient has the correct expectations of the different prosthetic options.
- More research about how patients form their expectancies can help give the health care professionals insight in the process a patient goes through when choosing a prosthetic option.

Besides factors concerning the expectancy the patients has of the myoelectric prosthesis, some other factors were found that could be improved the successful rehabilitation.

- Regular measurement of the patients' progress and communication of this progress with the patient can help keep the patient motivated.
- A person's occupation is a large part of a persons' daily life. Focusing the rehabilitation on the patients occupation makes sure the patient will use the prosthesis in his or her daily life in the right way, also when working.

CONTENT

CHAPTER ONE: INTRODUCTION

Limb loss is a potentially devastating event in a person's life, often resulting in profound physical, psychological and vocational consequences. (Dillingham et al., 2002). After amputation the patient can choose to wear a prosthesis. Different prosthetic options are available, this research will focus on the myoelectric arm-hand prosthetic. To be able to use the prosthetic in the right way, the patient will rehabilitate and train with the prosthetic guided by the physiotherapist and occupational therapist. This research will focus on the rehabilitation training with the myoelectric prosthetic. The goal of this research is to identify attributes which result in high effectiveness of the rehabilitation therapy for a myoelectric prosthesis according to the patients and the health care professionals.

UPPER LIMP AMPUTATION

Every year 2.086 people in the Netherlands undergo an amputation, of which 58 people undergo an arm-hand amputation. (Landelijke Vereniging Van Geamputeerden, 2006).

Trauma is the most common cause of upper limb loss, as is shown by statistics from prosthetic serviced centers in the United Kingdom (Information Services Devision NHSScotland, 2009). 53% percent of all the amputations were caused by trauma, and almost three quarters of all by trauma caused amputations are within the age of 16-54. Other causes of upper limb amputation are dysvascularity (11%) which are mainly Diabetes Mellitus related, neoplasia or new and abnormal growth of tissue(10%), infections (6%) and neurological disorders (1%). Besides the loss of an upper limb due to amputation, every year about 15 per 100.000 living births in the United States are born with a shorter upper limb. (National Limb Loss Information Centre, 2008) Amputations of the upper limbs usually occur at a young age; a mean age of 25-32 years was reported. (Datta, et al., 2004)

Because the different functions of the hand, like complicated motor functions but also the observance of the direct environment and non-verbal communication, the amputation of the arm is a great loss. (www.myopro.nl, 2010)

Rehabilitation is offered to the amputees to enable amputees to function in his or her own environment. A very important step towards this is that the person learns to accept his new state. For many amputees a prosthesis plays an important role in this process. (Lunteren et al., 1983)

PROSTHETIC

After an upper limb amputation a patient has several options for prosthesis, namely the passive prosthesis, the body-powered prosthesis, the electrically powered prosthesis, the myoelectric prosthesis, the hybrid prosthesis and the activity-specific prosthesis. All the different prosthetic types have the same basic construction. A synthetic socket, which is custom made using a plaster cast of the stump, covers the stump, and is the connection between the stump and the prosthetic hand. The artificial arm is connected to the socket and has the shape and length of the arm. Depending on the type of prosthetic the artificial arm can have electric parts. In case of a prosthetic with grasp function a separate hook or hand is attached. A cosmetic glove, which is available in different colors and types, gives the hand a natural look. (UMCG, 2009)

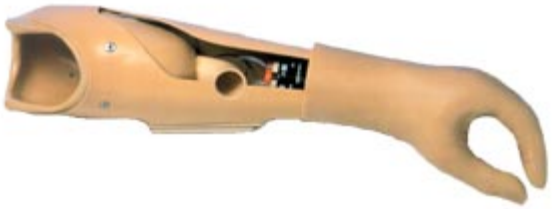

Figure 1: Myoelectric arm (source: The War Amps, 2010)

Figure 2: Myoelectric hand (source: Spears Prosthetics and Orthotics/Rehab Services, 2010)

Myoelectric prosthesis

Myoelectric prosthetics use myoelectrodes in the socket to collect and filter surface electromyogram signals generated through muscle contractions and convert those signals into a form that can influence electrical motors. The major disadvantage of a myoelectric prosthesis compared to other prosthesis options is its increased weight, which can cause muscle fatigue or friction about the residual limb. (Lake, 2006) The electrical motor opens en closes the myoelectric hand.

Most used myoelectric hands can open en close by contracting muscles in the stump, like the prosthetics shown in figures 1 and 2. Other myoelectric prostheses developed by Touch Bionics and Otto Bock, which are not commonly used in the Netherlands, have some extra grips.

REHABILITATION WITH A MYOELECTRIC PROSTHESIS

Following the amputation the treatment team and patient discuss preferences concerning the prosthesis. If the decision for a myoelectric prosthetic is made, the physiotherapist measures if the patient has the capabilities to use a myoelectric prosthesis and which muscles are suitable for placing the electrodes.

The patient starts with practicing using a practice hand (electrodes, which can be placed on the stump, are wired to a myoelectric hand). Guided by the physiotherapist, the patient learns to contract muscles independently of each other and surrounding muscles are trained as well. In the mean time the orthopedic instrument maker can construct the prosthesis.

When the prosthesis is finished, the patient visits the occupational therapist where he will learn to operate the prosthesis. At the occupational therapist the patient starts by learning to open en close the hand, to pick objects up and putting them down, to move the prosthesis and to dose the strength of the hand. Repeating the movements is very important. When patient is able to do these movements, two handed activities will be practiced. The goal of the training with the occupational therapist is to integrate the prosthesis in the daily activities of the patient. Beside that the occupational therapist also practices one handed activities with the patient. The training with the prosthesis will take several months.

The patient stays monitored by the treatment team to evaluate the prosthesis use and to stay up to date of the developments. An adaption technician can make specific adjustments, for example adjustments that allow the patient to handle specific objects like tools or musical instruments. (UMCG, 2009)

Research by Datta (1991) shows that in rehabilitation treatment for upper limb amputees, it is important to offer patients a multidisciplinary approach in providing a comprehensive rehabilitation program.

MYOELECTRIC TRAINING

Training with the myoelectric prosthesis accomplishes three important tasks: becoming accustomed to wearing the prosthesis, becoming efficient with the prosthesis and learning to view the prosthesis as a part of the body image. (Dupont et al., 1994)

Dawson et al. (2011) and Dupont et al. (1994) describe that myoelectric training is composed of three phases: signal, control and functional training.
Signal training involves using myoelectric testing devices, which display the patient's signal levels, to teach the patient how to activate, relax and isolate their individual signals. (Isolation of individual signals in conventional controllers is important in order to avoid co-contraction, which can cause undesired movements of the prostheses)
Control training uses more advanced myoelectric training systems, such as prostheses simulators, video games and robotic arms. These training systems teach the patient how to generate signals for conventional controllers and can also be used in the initial evaluation phase of the fitting in order to help gauge whether the patient is suitable for myoelectric fitting.
Functional training is usually performed with the actual myoelectric prostheses and helps the patient learn how to perform tasks for daily living. These tasks can start with basic motor skills such as grasping an object and move up to more advanced tasks such as recreational activities and basic hygiene.
Simon et al. (2012) describes a fourth stage of training: Prosthetic recalibration: Teaching the patient how to maintain performance of the prosthesis during everyday usage.
The quality of the training determines the use of the prosthesis for the rest of one's life. Not only the technical possibilities of a prosthesis determines the functional use, but also the functionality, the way the amputee is able to handle the prosthesis, which can be enhanced by training. (Bouwsema et al. 2008)

The effect of rehabilitation on the use of the myoelectric prosthesis
The clinical significance of myoelectric training is that it can potentially help increase a patient's competence and confidence in using their myoelectric prostheses. Correspondingly, this increase in comfort may also help increase the acceptance rates of myoelectric prostheses. In literature, training is emphasized as playing a key role in successful fittings of myoelectric devices in children. A few studies have shown that training did not have a significant effect on the acceptance rates in adults. These studies found that other more predominant factors, such as the amount of time between amputation and prostheses fitting, had a greater effect on acceptance rates in adults. The literature is lacking in clinical studies showing the specific effect of training tools on patient performance and acceptance rates. (Dawson et al., 2011)

Research about non-satisfaction and rejection of the prosthesis shows that besides the characteristics of the prosthesis and characteristics of the patient, factors concerning the rehabilitation play an important role in the patient satisfaction with their prosthesis. Different articles show that lack of training with the prosthesis or bad quality of the training results in nonuse of the prosthesis (Biddiss et al, 2007A; Biddiss et al, 2008; Resnik et al., 2012, Bouwsema et al, 2008) This suggests that identifying patients needs concerning the rehabilitation therapy can result in higher compliance for the rehabilitation and the prosthesis use. Datta (1991) states that patients' needs and views must be at the forefront in formulating the rehabilitation program.

RESEARCH QUESTION

The goal of this research is to identify attributes which result in high effectiveness of the rehabilitation therapy for a myoelectric prosthesis according to the patients and the health care professionals.

The following research question was formulated:

'What attributes expect patients and health care professionals to be relevant for the effectiveness of a rehabilitation therapy with a myoelectric prosthesis?"

The following sub questions were formulated:

- What attributes are related to the effectiveness of the rehabilitation therapy according to patients and health care professionals?
- How important do patients and health care professionals expect these attributes to be for an effective rehabilitation?
- Which recommendations can be given for the design of the rehabilitation therapy based on the identified attributes?

To answer this research question and sub questions data was collected in multiple stages. First a literature search was done which is described in the chapter two. After that data was collected by means of interviews with health care professionals in two rehabilitation centers in the Netherlands and patient questionnaires. This is described in chapter three.

METHODS – LITERATURE SEARCH

To find out what is known from the literature regarding attributes which result in high effectiveness of the rehabilitation and successful use of the myoelectric upper limb prosthesis a systematic literature search is done.

For the literature search, the Scopus database was used. The complete search strategy can be found in appendix A. The search contained the following terms in different combination: upper limb, prosthe*, rehabilitation, training, myoelectric, virtual, adherence, compliance.

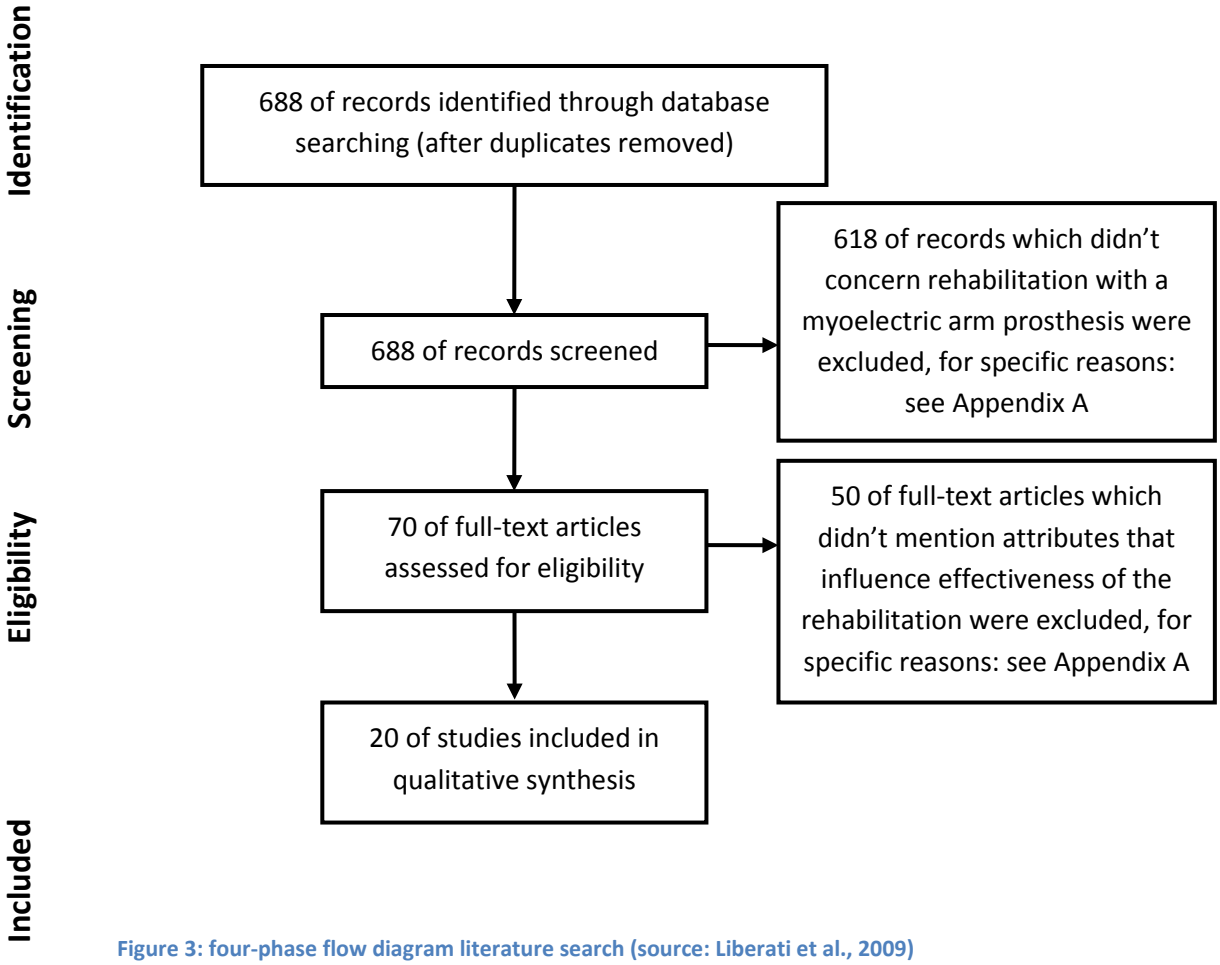

Figure 3: four-phase flow diagram literature search (source: Liberati et al., 2009)

RESULTS – LITERATURE SEARCH

Factors which are related to effective rehabilitation and successful use of a myoelectric upper limb prosthesis

To structure the factors found in literature the UTAUT model will be used. The UTAUT model is originally formulated to explain the acceptance of IT in organizations, but it is also applicable to health care innovations. Based on eight different behavioral models regarding adopting technology, a unified theory was formed. The Unified Theory of Acceptance and Use of Technology (UTAUT), as described by Venkatesh et al. (2003), points out four areas which influence the behavioral intention to use (accept) the technology, namely the performance expectancy, the effort expectancy, social influence and facilitating conditions.

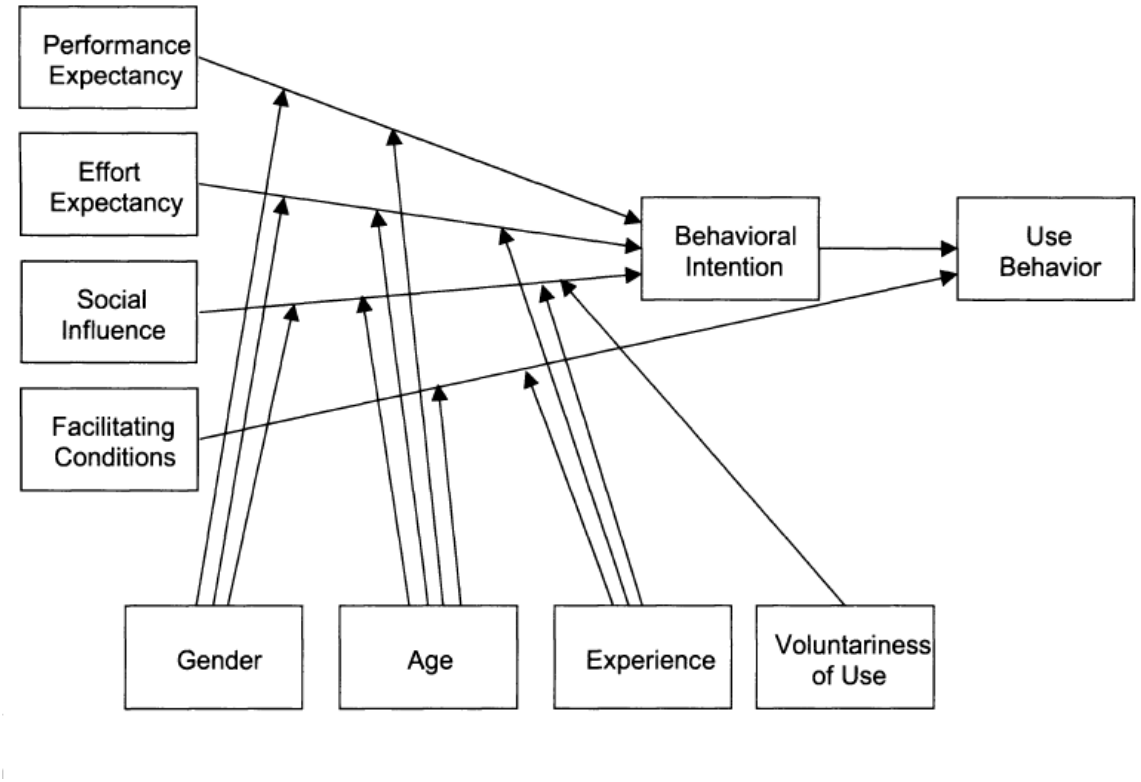

Figure 4: Unified Theory of Acceptance and Use of Technology (Venkatesh et al, 2003)

Although the research focuses on the therapy and not on the technology, the UTAUT can help categorize the found factors that influence the effectiveness of the rehabilitation therapy and the successful use of the myoelectric hand into the four areas.

Performance expectancy

The original definition of "Performance Expectancy" as defined by Vankatesh et al. (2003) was 'perception that using the system will help the user attain gains in job performance'. Because this research focuses on the rehabilitation therapy for the myoelectric hand, the performance expectancy

will concern the results the patient expects from following the therapy and using the myoelectric prosthesis.

Patients who experience a higher perceived need of the prosthesis in daily life are more likely to use the prosthetic upper limb successful. (Biddiss et al, 2007A; Biddiss et al., 2008) Biddiss et al. (2007A) state that nurturing accurate and realistic expectations on prosthesis use is essential to prevent prosthesis rejection owing to disappointment. In particular, comprehensive information regarding the challenges to be expected, available prostheses, prosthetic options and resources for support is demand. Also O'Keeffe (2011) concludes that outcome dissatisfaction is often the result of poor initial communication and unrealistic outcome goals being promised. Berke et al. (2010) concludes from his research that people who feel well educated about their prosthesis care are more likely to adherence to treatment recommendations and have improved health outcomes.

Effort expectancy

The "effort expectancy" is described by Venkatesh et al. (2003) as "the perception of the degree of ease associated with using the system". In this research the effort expectancy will be the effort it takes to complete the therapy and to control the prosthesis.

Takeuchi et al. (2007) shows the importance of the training not being too easy or too difficult and adjusted to the patients' level. Experimental results show that control ability of the EMG signal of the subject is significantly improved with the training method where the difficulty was controlled based on the results, compared to training were the difficulty was not depending on the results. Wada et al. (2008) showed with the training they developed that the efficacy of the training strongly depends on the task difficulty or success rate in the training phase. Bouwsema et al. (2008) researched the effect of the training structure on the efficacy of the training with a prosthesis. The research compared the efficacy of training in a random order or training in a blocked order, the last meaning practicing all trails of one task before the next task is introduced. Performance in daily life is indifferent to the structure in which the training is set up. However, practicing in a blocked fashion leads to faster performance.

Scheme et al. (2011) concludes that because a training session has poor resilience from day to day, it is important that the time and complexity of the training session is sufficiently low enough to be performed easily by the user on a daily basis. Herle et al. (2008) describes an approach with EMG signal classification which results in lower total training time to be invested resulting in a more successful rehabilitation process.

Social influence

Venkatesh et al. (2003) described the "social influence" as "the perception of important (or relevant) other beliefs about person's use of system". In case of this research this perception of the people surrounding the patient about following the rehabilitation therapy and using a myoelectric prosthesis.

Psychosocial factors are likely to play a crucial role in adjustment to upper limb amputation and prosthesis use. (Saradjian et al., 2008) Saradjian et al. (2008) researched the coping and feeling

different in social interactions among men whom had undergone an upper limb amputation. Saradjian et al., (2008) states that a prosthesis can facilitate the patient's wish of feeling normal and can help manage social interactions.

Structure trainings program

The ATAUT model is developed to point out four areas that influence the use of a technology, based on an existing technology. In this research the UTAUT model is used to structure aspects that influence the success of the rehabilitation therapy. Literature shows different changeable aspects concerning the structure of the trainings program which influences the successful use of a myoelectric prosthesis. For that reason a new category is added. This category contains factors that change the structure of the rehabilitation program.

Research by Biddiss et al. (2007A; 2008) and Pezzin et al., (2004) show that the fitting time after amputation influences successful use of the myoelectric prosthesis: patients who are fitted within six months after amputation are more likely to continue prosthesis use than who are not.

Saradjian et al. (2008) researched the coping and feeling different among men whom had undergone an upper limb amputation. Saradjian et al. (2008) state that rehabilitation is more successful when individuals accept the impact of their disability and engage in the process of adapting to the multifaceted changes that disability involves. It also shows the individuality of the rehabilitation process and the use and role of prostheses in facilitating this. It is therefore important to engage the individual in this process as much as possible in order to maximize the potential of prostheses and optimize rehabilitation. The findings of his research also suggest a value in providing social skills training like those used for people with disfigurements.

Patient motivation and psychological counseling undoubtedly play a major role in a successful prosthetic rehabilitation. (Bhaskaranand et al., 2003)

Insufficient follow-up and lack of ongoing training have been implicated as possible causes for high rejection rates and have been specified as areas of importance. (Biddiss et al. 2007B) Ongoing psychological care and counseling appear to be important aspects of rehabilitative follow-up.

Reasearch by Biddiss et al. (2007A; 2008) mentioned the importance of the patients influence in the decision for a prosthesis type: when a patient is involved in the selection of his/her prosthesis this increases the likelihood of its acceptance.

Facilitating conditions

The "Facilitating Conditions" are described by Venkatesh et al. (2003) as "the perception that organizational and technical infrastructure exist to support using the system". For this research about the rehabilitation therapy facilitating conditions will concern conditions which support finishing the therapy and using the myoelectric prosthesis and don't concern the structure of the rehabilitation program.

Different researches show that patients do not use their prosthesis caused by financial aspects. The

prosthesis and its maintenance is too expensive and/or no funding is available. (Bhaskaranand, 2003; Dakpa et al., 1997; Roeschlein et al., 1989)

Technical aspects of the prosthesis are in some studies found as reason for non succesfull prosthetis use. (Bhaskaranand, 2003; Gaine et al., 1997; Biddiss et al, 2007A; Biddiss et al., 2008)

Pezzin et al. (2004) points out that despite being generally satisfied with items related to the technical skills and information-giving abilities of prosthetists, a significant proportion of persons with amputations had negative perceptions regarding their prosthetists manner. Efforts should be made at improving communication between patients and prosthetists. Dakpa et al. (1997) also points out non-satisfaction of patients with their prosthesis caused by lack of effective communication.

Moderating factors

The UTAUT model by Venkatesh et al., (2003) also uses four key moderators of the relationships between the determinants and intention and use: age, gender, experience and voluntariness of use. In literature different patient characteristics were found which influence upper limb prosthetic use, which can't be influenced by the rehabilitation therapy. These are factors that can be use to describe the sample and should be taken into account when analyzing the results.

Different researches found the effect of age on successful prosthetic use. Younger patients are more likely to use their prosthetic upper limb successfully. (Bhaskaranand, 2003; Biddiss et al, 2007A; Biddiss et al., 2008) Also gender is a predisposing factor in the prosthetic rehabilitation of upper limb amputees, males are more successful. (Biddiss et al, 2007A; Biddiss et al., 2008).

The occupational status of the patients correlates with the use of prosthetic upper limbs. Patients with a (fulltime) job are more likely to successfully use their prosthetic arm. (Biddiss et al, 2007A; Roeschlein et al.,1989)

Different researches show the effect of educational and learning aspects on the successful use of a myoelectric prosthesis. Research by Bouwsema et al. (2010) compares three different types of myoelectric signal training: training with a myoelectric virtual hand presented on a computer screen, training with an isolated prosthetic hand, and training with a prosthetic simulator. No differences were found between the three types of training. Prosthetic learning does not depend on the type of training. Prosthetic users may differ in learning capacity, and this should be taken into account when choosing the appropriate type of control for each patient, thus Bouwsema et al. (2010). Research bij (Roeschlein et al., 1989) shows that patients who had finished school with a higher level of education were more likely to successfully use their prosthetic upper limb. Also a correlation is found between the literacy of patients and successful prosthetic use. (Hrnack et al., 2009)

Medical aspects of patients influence prosthetic use. Patients with complication conditions are less successful in using their prosthesis. (Roeschlein et al., 1989) Rejection rate of upper limb prosthetics are higher in patients with low- and high level of limb absence. (Biddiss et al, 2007A; Biddiss et al., 2008; Raichle et al., 2008) Patients who experience phantom and/or stump pain are less likely to successful use their upper limb prosthesis. (Bhaskaranand, 2003; Gaine et al., 1997)

Lovely et al. (1990) states that from the literature and local experience the patient's motivation rather than any other criterion is the limiting factor determining the duration and effectiveness in signal training.

The literature search showed factors which influence the successful rehabilitation and use of the myoelectric hand prosthesis according to the literature. The factors found in the categories performance expectancy, effort expectancy and structure of the trainings program can be changed by the rehabilitation therapy. These factors should be taken into account in designing and offering the rehabilitation therapy according to the literature. The facilitating factors are changeable, not by the rehabilitation therapy, but on a larger level. The perceived influences of all these factors will be asked from patients and health care professionals. The moderating factors are patient characteristics and can't be changed or influenced.

The factors will be used in the next part of this research. In the interviews with the health care professionals they will be asked to score the importance of these factors for the successful rehabilitation and successful use of the myoelectric hand prosthesis. Also in the patient questionnaires the patients will be asked about the importance of these factors, combined with new factors which were mentioned in the interviews with the health care professionals.

CHAPTER THREE: INTERVIEWS WITH HEALTH CARE PROFESSIONALS AND PATIENT QUESTIONNAIRES

In this stage of the research data was collected by means of interviews with health care professionals and questionnaires for patients. Goals of this stage is identifying attributes besides the ones found in literature which can influence successful rehabilitation and use of the myoelectric hand prosthesis, and identifying the importance of the found attributes according to the health care professionals and patients. A list of all the attributes resulting from the literature search and interviews with health care professionals can be found in Appendix B.

METHODS – INTERVIEWS WITH HEALTH CARE PROFESSIONALS AND PATIENT QUESTIONNARES

Interviews with health care professionals

Data was collected by means of semi structured interviews with professionals from two rehabilitation centers; Enschede and Groningen. In Enschede a rehabilitation physician, a physiotherapist and an orthopedic technician were interviewed. In Groningen a rehabilitation physician and an occupational therapist were interviewed. The interview questions which were used can be found in Appendix C.

Different questions were asked to find characteristics which result in high compliance. The semi structured interview makes sure that all elements of the rehabilitation treatment will be discussed, but allows new questions responding to participants' answers. The interviews were recorded.

At the end of the interview a list of characteristics which were found in literature were shown to the interviewees. This list can be found in Appendix C. On a rating scale from no influence at all to very large influence the interviewees scored the characteristics.

score				
No influence at all				Very large influence
1	2	3	4	5

Patient questionnaire using Analytic Hierarchy Process (AHP)

After the interviews with health care professionals data was collected by means of questionnaires for patients. Goal of these questionnaires was to find the relative importance of the attributes resulting from the literature search and the interviews with health care professionals, according to the patients' perception. A list of all the attributes which were used in the patient questionnaire can be found in Appendix B. To find the relative importance the Analytic Hierarchy Process (AHP), a multi criteria decision analysis technique developed by Saaty (1980) was used.

The Analytic Hierarchy Process (AHP), a method developed by Saaty (1980), is more and more used in health care. A main strength of the AHP is that it is both methodological sound and user-friendly (Dolan, 2008). All inputs consist of comparison between just two elements at a time. Reynolds (1980) states that pairwise comparisons like used in the AHP are generally considered to be one of the best ways to elicit judgments from people.

The analytic hierarchy process exists of four steps. The first step is to define the problem and the goal of the decision. In this research the goal of the AHP to make a priority list of the found attributes. The

second step is to structure the hierarchy. On top the goal of the AHP, followed by the objectives (attributes).

After the hierarchy is build the questionnaire with the pairwise comparison can be structured. With the pairwise comparison the patients are asked to compare the importance of the attributes. On a nine points scale patients point out the relative importance of the factor, 1 means the two factors are equally important and 9 means that one of the attribute is extremely more important. (Saaty, 2008)

For example:

Circle one number per row below using the scale:
1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme

1	Total time investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Contact with physician

Figure 5: Example of pairwise comparison in questionnaire

The questionnaire will started with questions about the patient's history, personal and medical. After that the patient is asked to pairwise compare the found attributes, separate for each category of the UTAUT model described in the previous chapter. The last questions of the interview are the pairwise comparison of the different categories of the UTAUT model. A total list with all the attributes used in the questionnaires can be found in Appendix B.

The final step of the AHP is to calculate weighing factors of the attributes. For data-analysis and sensitivity analysis of the AHP, the 'Expert Choice' software package was used. The weights that were calculated represent the relative importance of the attributes.

In order to contact the patients, two patient associations in the Netherlands were contacted if they want to place a notice on their website with a link to the online questionnaire. One of the two associations placed the notice. Despite several emails to different board members and phone calls, making contact with other patient association failed.
The five health care professionals who were interviewed were asked if they could forward an email or letter with the notice to patients. The rehabilitation centre in Groningen already used their patient database for two other studies. The rehabilitation physician from Enschede offered to send a letter to a group of patients he treated in the rehabilitation center in Enschede the last few years.
The research population existed of 11 adult patients who had undergone an below-elbow arm-hand amputation or are born with a shortening of a arm, and who are using or started using a myoelectric prosthetic. No further limitation was used because of the small group of patients. 11 patients started the questionnaire. Not all patients finished it, the last question was answered by 7 patients. Because of the low number of patients, the patients who only finished the first (few) pair wise comparison(s) that had a low inconsistency were included in this research. All the other patients' comparisons had a low inconsistency, so no patients needed to be eliminated caused by that.

Analysis

Literature search and the interviews have shown attributes which influence the successfulness of the rehabilitation treatment. These attributes were ranked by patients using the AHP pairwise comparison which results in a priority list and a relative importance for each attribute.

The attributes found in literature were scored by the health care professionals on a scale from 1 to 5.

To be able to compare the scores given by the interviewees with the relative importance given by the patients, the scores of the health care professionals will be standardized into relative importance. First the scores on the scale from 1 to 5 given by the different health care professionals are added and divided by the number of health care professionals resulting in an average score. Then for each category the average scores were added. To calculate the relative importance of an attribute, the average score for one attribute is divided by the added scores of all the attributes in the category.

RESULTS – INTERVIEWS WITH HEALTH CARE PROFESSIONALS AND PATIENT QUESTIONNAIRES

The results of the interviews and questionnaires will be discussed in the categories of the UTAUT model described in the previous chapter. The tables show the standardized scores from the interviewees at the end of the interview, and relative importance given by the patients.

Performance expectancy

During the interviews with the health care professionals several comments were made about the performance expectancy of patients with regard to the myoelectric rehabilitation and prosthesis use. According to four out of five health care professionals, one of the most frequent reasons why patients don't finish the training or stop using the prosthesis is the wrong (and often high) expectations some patients have of the myoelectric prosthesis.
Two interviewees mentioned that many patients start the rehabilitation thinking the myoelectric prosthesis will replace their missing arm. Instead the prosthesis is an aid which helps in daily activities when missing an arm. However, changing wrong expectations of patients is thought to be very difficult.
One of the interviewees wishes to learn more about how patients make a decision for a certain type of prosthesis and how patients form their expectations of the prosthesis. When physicians and therapists have a better understanding of this process of expectations and decision, they are more capable of guiding the patients in this process and preventing patients for making the wrong choices and developing wrong expectations.
All five interviewed care givers suggested that giving the patients enough, accurate and realistic information about the prosthesis and the rehabilitation process is very important.

At the end of the interview the health care professionals was asked to score the 3 factors related to the performance expectancy which were found in literature. The health care professionals scored the 'Realistic expectations on prosthesis use in daily life' highest, and mentioned it in the interviews as very important. In contrary, the patients who pairwise compared the 3 factors in the questionnaire ranked this factor lowest in this category. The patients ranked the 'Perceived need of the prosthesis in daily life' as the most important factor in this category.

The health care professionals and patients agree on the importance of the category 'Performance expectancy' compared to the other categories. Both the health care professionals and the patients ranked this category the most important.

	Interviews health care professionals	Patient questionnaires
	Standardized relative importance	**Relative importance**
1. Perceived need of the prosthesis in daily life	**0.313**	**0.596**
2. Accurate expectations on prosthesis use in daily life	**0.313**	**0.287**
3. Realistic expectations on prosthesis use in daily life	**0.373**	**0.117**
All factors Perfomance Expectancy combined	**0.227**	**0.321**

Effort expectancy

During the interview a view comments were made about factors concerning the category 'Effort expectancy' which were also found in literature. One interviewee mentioned that some patients stop the trainings program because the training is difficult and takes more time and effort than expected. One interviewee mentioned that it is important to adjust the training to the capabilities and expectations of the patient.

The interviewees mentioned some new factors in the category effort expectancy which were not found in literature.

Training more times a week can fasten the rehabilitation process and prevent patient teaching themselves wrong habits after the prosthesis is finished. Now patients visit the rehabilitation centre ones or twice a week.

One of the interviewees wishes there were more regular measurements for this patient group. There are functional tests that are used in the current rehabilitation, but they are not specifically designed for arm amputees using a myoelectric prosthesis. A specific functional test for this group of patients can help designing the rehabilitation process, tracking patient's improvements and improve patient's motivation by working towards a goal.

Focusing the training on how the patient can use the prosthesis in his or her occupation will help increase prosthetic use after the rehabilitation is finished.

The interviewed physicians and therapists made some comments about the possibilities for using games and virtual reality in the rehabilitation with a myoelectric prosthesis. Both rehabilitation centers use the MyoBoy program, developed by Otto Bock (2010). In this computer program the patient can control a car using myoelectric signals. Although all the interviewed physicians and therapists don't have experience with other games besides the MyoBoy and have no experience training with virtual reality, they see advantages of using games and virtual reality:

- Motivation is a very important aspect in the training with a myoelectric prosthesis. The fun of playing games can keep the patient motivated. (mentioned in four of the five interviews)
- Using games or virtual reality offers the possibility of training the muscles used for myoelectric control before the prosthesis is made.
- In a computer game or virtual reality environment it is possible to adjust the training to the patient's level and gradually complicate the training.
- The progress of a patient can be made visible when using a computer game or virtual reality environment.

- Different kind of feedback can be given, like audio and visual effects.
- When training with a computer game or in a virtual reality, the patient doesn't experience the weight, sweating and discomfort of the prosthesis. This has the advantage that the discomfort doesn't interfere with training the muscles used for myoelectric control, but it cannot replace training with an actual prosthesis because of that.

Some of the interviewees wish that a computer game will be developed which patients also can use at home. When patients have an opportunity to train at home, they can increase the amount of training moments and can finish the rehabilitation faster.

The ranking by patients and health care professionals show that the patients and the health care professionals agree that factors like the difficulty and training time are less important than the patient's expectations and insight of the rehabilitation.
From the factors that were new mentioned in het interviews the 'Regular measurements of the patient's progress' and 'Focusing the training on the patient's occupation' are ranked as relative important by the patients.
The factors concerning the virtual reality and games are ranked as relative not important.

This category is scored as important by the patients, while the health care professionals scored the factors in this category not so high. Hereby should be mentioned that the in the patient questionnaire there were five more factors in this category compared to the questionnaire for health care professionals, because the health care professionals mentioned some new factors within this category.

	Interviews health care professionals	**Patient questionnaires**
	Standardized relative importance	**Relative importance**
4. Difficulty of the training	**0.189**	**0.114**
5. The training meets the expectations of the patients	**0.221**	**0.169**
6. Time and complexity of the training session	**0.189**	**0.076**
7. Total training time	**0.179**	**0.059**
8. The patient has insight in the goal and course of the training	**0.221**	**0.117**
9. Training more times a week for faster rehabilitation	**-**	**0.058**
10. Regular measurements of the patients progress	**-**	**0.138**
11. Focussing the training on a patients occupation	**-**	**0.178**
12. The possibility of training with computer games or VR at the rehabilitation centre	**-**	**0.042**
13. The possibility of training with computer games or VR at home	**-**	**0.050**
All factors Effort Expectancy combined	**0.187**	**0.292**

Social influence

Some of the interviewed health care professionals mentioned that involving the social environment of a patient in the rehabilitation is very important. The people who join the patient to the consults can be more involved. However, sometimes the wish for a (myoelectric) prosthesis originates stronger from the social environment of the patient than from the patient. Often these patients don't finish the rehabilitation process or eventually don't use the prosthesis.

Concerning social influences on the effectiveness of the rehabilitation there is a large disagreement between the patients and health care professionals. Where the health care professionals feel that the influence of the social environment is quite important on the successful rehabilitation, the patient ranked this category as the least important. Notable is the high relative importance the patients gave "the extent to which the patients is feeling different in social interactions caused by the prosthesis", especially compared the low relative importance the patients gave to "the extent to which the patient is feeling different caused by the amputation".

	Interviews health care professionals	**Patient questionnaires**
	Standardized relative importance	**Relative importance**
14. Support from the social environment of the patient (partner, close family, friends)	**0.266**	**0.210**
15. Support from the medical environment of the patient (therapists, doctors, nurses)	**0.241**	**0.203**
16. The extent to which the patient is feeling different in social interactions causes by the amputation	**0.253**	**0.137**
17. The extent to which the patient is feeling different in social interactions causes by the prosthesis	**0.241**	**0.450**
All factors Social Influence combined	**0.202**	**0.105**

Structure trainings program

Four out of the five interviewed health care professionals suggested that starting the rehabilitation process soon after the amputation results in higher compliance. In contrary, some health care professionals mentioned that the training with the prosthesis can't start until the stump is healed. Three interviewed health care professionals suggested that seeing the patients annually and checking whether the patient is using the prosthesis in the right way after the rehabilitation will improve the use of the prosthesis in the patient's daily life. This is important to prevent straining. When looking at the ranking from the patients and health care professionals it is noticeable that the health care professionals scored the 'Follow-up after finishing the rehabilitation program' as quite high, where the patients scored that as relative not important.

Four interviewees stated that it is important to find out what the goals of the patient are for using the myoelectric prosthesis in the beginning of the rehabilitation, to find out if the myoelectric

prosthesis is the appropriate prosthesis type for reaching those goals, and to arrange the training program towards those goals. Sometimes all a patient wants is an extra hand to hold on to objects like a piece of paper when writing.

One of the interviewees mentioned a new factor which wasn't found in the literature search. In the current situation patients don't have the option to try different prosthesis before making a decision. It would be good if the rehabilitation centre would have examples of different prosthetic options to show the patients. That can help giving the patients the correct expectations of the different prosthetic options. And if the insurance companies would compensate for the synthetic socket for every patient, whether the patients chooses a prosthesis or not, then the patients can try the different prosthetic options. One of the interviewees thinks it would be good for all patients to start with a simple prosthetic option. If the patient wishes he or she can choose a more advanced prosthetic option later. That would prevent that patients choose a prosthesis which is too difficult for them. This new mentioned characteristic by the health care professional 'The opportunity to try different prosthetic options before deciding' has a very high relative importance given by the patients.

The category 'Structure of the trainings program' was ranked average compared to the other categories by both the health care professionals as the patients.

	Interviews health care professionals	**Patient questionnaires**
	Standardized relative importance	**Relative importance**
18. Fitting time after amputation	**0.215**	**0.138**
19. Providing social skill training for dealing with the amputation and prosthesis in social interactions	**0.172**	**0.110**
20. Offering psychological counseling	**0.194**	**0.067**
21. Follow-up after finishing the rehabilitation program	**0.226**	**0.065**
22. The patient has a large influence on the decision for the prosthesis type	**0.194**	**0.254**
23. The opportunity to try different prosthetic options before deciding	**-**	**0.366**
All factors Structure trainings program combined	**0.197**	**0.168**

Facilitating conditions

The interviewed health care professionals made several comments concerning the facilitating conditions of the rehabilitation with a myoelectric arm prosthesis.

Financial aspects caused by the insurance companies influence whether a patient can choose a myoelectric prosthesis and the success of the rehabilitation:

- Funding a myoelectric prosthesis for patients with an arm amputation isn't the norm. The rehabilitation team must give the insurance companies good reasons for funding a

(expensive) myoelectric prosthesis instead of a (cheaper) bodypowered or cosmetic prosthesis.
- One of the interviewed health care professionals mentioned that the newest most inventive myoelectric prostheses are not funded by the insurance companies.
- The insurance companies take longer time then necessary before approving and funding the prosthesis. It would be better to start the rehabilitation sooner.

All of the interviewed health care professionals mentioned that (technical) aspects of the myoelectric prosthesis influence whether the patient chooses a myoelectric prosthesis, finish the training program and use the prosthesis in their daily life:
- The myoelectric prosthesis has more functionality.
- Two interviewees mentioned the shortcomings of the myoelectric prosthesis. For example, you can't feel objects whit the prosthesis, a visual feedback is always necessary.
- Four of the interviewed health care professionals mentioned that the myoelectric prosthesis is heavy and sweaty, compared to the other prosthetic options.
- The myoelectric prosthesis is more difficult to control than other prostheses like the body-powered prosthesis. For some patients the stump is not suitable for controlling the myoelectric prosthesis.
- The cosmetics of the myoelectric prosthesis are for some patients a reason for choosing another prosthetic option.
- The myoelectric prosthesis is more vulnerable compared to the other prosthetic options because of the electronics.
- There are patients who don't feel for wearing and using an electronic devise on their body.

Two of the interviewees think centralization of the rehabilitation of arm amputees into a few rehabilitation centers in the Netherlands should be a good development. Because of the small patient group the current centers that treat these patients see only a few patients. If the care is more centralized, a few physicians and therapist can specialize in the care for these patients, and as they will see more patients the care for this group will improve. One of the interviewed health care professionals points out that he doesn't know if the rehabilitation is optimal, because of the small number of patients he treats. The downside of centralization is that patients have to travel further to visit the health care professionals. The ranking from the patient questionnaire shows that the patients don't think that whether there a lot or a few rehabilitation centers has a large influence on the success of the rehabilitation.

When asked to rate the factors which were found in literature the health care professionals scored the "Communication between patient and prosthesist" as very important for successful rehabilitation. The patient gave 'Funding of the costs for the prosthesis and training' and '(Technical) aspects of the prosthesis' the highest relative importance.

Both the patients as the health care professionals scored that the category 'Facilitating conditions' has a low importance for successful rehabilitation with a myoelectric prosthesis.

	Interviews health care professionals	Patient questionnaires
	Standardized relative importance	**Relative importance**
24. Funding of the costs for the prosthesis and training	**0.339**	**0.351**
25. (Technical) aspects of the prosthesis	**0.268**	**0.311**
26. Communication between patients and prosthetists	**0.393**	**0.136**
27. One or a view specialized rehabilitation centers	**-**	**0.156**
28. Many rehabilitation centers nearby patients	**-**	**0.046**
All factors Facilitating conditions combined	**0.187**	**0.114**

Categories of the UTAUT model

The standardized relative importance scored by the health care professional for each of the categories of the UTAUT model can be found in the following table.

The last question of the questionnaire for the patients asked the patients to weigh the five categories.

The patients and health care professionals agree that the 'Performance expectancy' is the most important category, and that the 'Facilitating conditions' are the least importance for successful rehabilitation with a myoelectric prosthesis.

The patients and health care professionals don't agree completely on the importance of the categories 'Effort expectancy' and 'Social Influences'.

	Interviews health care professionals	Patient questionnaires
	Standardized relative importance	**Relative importance**
All factors Perfomance Expectancy combined	**0.227**	**0.321**
All factors Effort Expectancy combined	**0.187**	**0.292**
All factors Social Influence combined	**0.202**	**0.105**
All factors Structure trainings program combined	**0.197**	**0.168**
All factors Facilitating conditions combined	**0.187**	**0.114**

Moderating factors

Moderating factors are patient characteristics that can't be influences.

Some interviewed health care professionals mentioned that medical aspects can cause patients to stop the training with the myoelectric prosthesis or stop using the prosthesis.

- Some patient experience a lot of stump pain, for these patients it is more difficult to wear a myoelectric prosthesis, because of the weight.
- Infection on the stump sometime causes patients to stop with the training.
- For patients with a high amputation it is more difficult to control the myoelectric prosthesis.
- How the amputation is done influences whether a patient can use a (myoelectric) prosthesis.

An often mentioned patient characteristic which influences the success of the rehabilitation and prosthesis use is the patient's motivation. In contrary to the other characteristics in this category, the patient's motivation is partly changeable. Some of the previous mentioned characteristics from other categories have an influence on the patient motivation, but besides that the patient has to have a strong internal motivation for rehabilitating with a myoelectric prosthesis and for using the prosthesis in his or her daily life.

A patient characteristic which wasn't found in literature, but was mentioned by some health care professionals is that there is a difference between patients in how soon they can learn new motor skills. Patients who are more athletic often learn to control the prosthesis faster.

These moderating factors were not part of the patient's questionnaire. Because the health care professionals have seen a number of patients, they can compare the success of the rehabilitation for patients with different characteristics. Compared to all the other categories the health care professionals scored the moderating factors lowest.

	Interviews health care professionals
Factors	**Standardized relative importance**
29. The age of the patient	**0.087**
30. The gender of the patient	**0.072**
31. Earlier positive experiences with prostheses	**0.123**
32. Earlier negative experiences with prostheses	**0.138**
33. The occupational status of the patient	**0.145**
34. Educational and learning aspects of the patient	**0.116**
35. Medical aspects of the patient	**0.145**
36. A patient's motivation	**0.174**

DISCUSSION AND CONCLUSION

The aim of this research is to identify factors which influence the success of a rehabilitation trainings program for a myoelectric prosthesis according to patients and health care professionals, with the goal to suggest recommendations in the current rehabilitation program. Data was collected by means of a literature search, interviews with health care professionals and patient's questionnaires. First the results of this study will be discussed.

The results show that patients and health care professionals agree that the factors concerning the "Performance Expectancy" have the largest influence on the effectiveness of the rehabilitation therapy. All five interviewed health care professionals mentioned the importance of patients having the correct expectations about the myoelectric prosthesis. Also literature shows the importance of giving the patients realistic and accurate information about the prosthetic options (Biddiss et al., 2007A, 2008; Berke et al., 2010). However, research by Berke et al. (2010) also shows that a concern across all his survey participants was the dearth of information available to individuals with limb loss on new prosthetic devices.
Besides the information given by the health care professionals, internet provides a lot of information which isn't always accurate or realistic. Some health care professionals mentioned that patients already formed expectations about the myoelectric prosthesis before visiting the health care professionals. Changing patients' expectations is thought to be very difficult according to the interviewed health care professionals. This suggests that besides the importance of giving the patients accurate and realistic information it is also important to give this information in an early stage to prevent the patients from constructing wrong expectations.

Disagreement between patients and health care professionals

While the patients and health care professionals agree on what is most important for a successful rehabilitation, there is also a lot of disagreement on the importance of other factors.

A difference in the ranking from the patients and health care professionals is the importance of the effort expectancy the patient has of the training. This category is scored as important by the patients, while the health care professionals scored the factors in this category not so high. Hereby should be mentioned that the in the patient questionnaire there were five more factors in this category compared to the questionnaire for health care professionals, because the health care professionals mentioned some new factors within this category.
Although the literature shows the importance of the training time per session (Scheme et al., 2011) and the total training time (Herle et al., 2008), looking at the ranking from both the patients and the health care professionals, the results suggest that the training time doesn't have a great influence on the successful rehabilitation with a myoelectric prosthesis. Also the in the interview mentioned option to train more times a week for a faster rehabilitation scored low in the patient ranking. Looking at the results, the patients' expectations and insight in the training are more important.

A remarkable difference between the answers of the patients and health care professionals is concerning the importance of the patient's influence on the decision for the prosthesis type. The health care professionals scored this relative low, where the patients ranked this as quite important for a successful rehabilitation. The patient questionnaire started with some general questions. One of

those questions was about the main reason why the patient has chosen to use a myoelectric prosthesis. Two out of eleven patients answered that the rehabilitation physician has chosen for them, and one patient answered that he tried the prosthesis because the physician recommended it. So not in all cases the patient had al large influence on the prosthesis type.
Two of the health care professionals mentioned during the interview that it is very difficult for patients to choose a type of prosthesis. Possibly some health care professionals think it is better to choose for the patients, because it is hard for patients to imagine what the different type of prosthetics will do for them.
Reasearch by Biddiss et al. (2007A; 2008) mentioned the importance of the patients influence in the decision for a prosthesis type: when a patient is involved in the selection of his/her prosthesis this increases the likelihood of its acceptance.
As one of the interviewees mentioned, learning about how and why patients choose a myoelectric prosthesis, and how the patients expectations about the prosthesis are formed can prevent that patients make the wrong decision. If the health care professionals learn more about this process, they could possibly be more helpful in guiding the patient in choosing the right prosthetic option without making the decision for the patient.

Another remarkable difference between the answers of the patients and the health care professionals is the importance of the follow-up after finishing the rehabilitation program. The health care professionals think this has a large influence on successful rehabilitation where the patients gave this factor a very low relative importance. Three of the interviewees mentioned the importance of the follow-up. A possible cause of this difference is that the health care professionals can learn from the experiences of patients and can use this knowledge when working with new patients. Another possible reason for this difference in opinion can be, as one of the interviewed health care professionals mentioned; some patients think that they are using the prosthesis in the right way, while the health care professionals still see room for improvement.

Concerning Social influences on the effectiveness of the rehabilitation there is a large disagreement between the patients and health care professionals. Where the health care professionals feel that the influence of the social environment is quite important on the successful rehabilitation, the patient ranked this category as the least important. Literature showed very little about the influence of the social environment in the rehabilitation with a prosthetic.
Notable is the high relative importance the patients gave “the extent to which the patients is feeling different in social interactions caused by the prosthesis”, especially compared to the low relative importance the patients gave to “the extent to which the patient is feeling different caused by the amputation”. Saradjian et al., (2008) states that a prosthesis can facilitate the patient’s wish of feeling normal and can help manage social interactions. The prosthesis can help a patient feel normal after an amputation, but the results suggest that the prosthesis is also a cause of feeling different by the patient. Taking this into account the low score on “providing social skill training for dealing with the amputation and prosthesis in social interactions” in the category “Structure training program” is remarkable. This suggests that offering the patient social skill training is not the solution according to the patients.

Additional factors the theoretical model from interviews with health care professionals

The health care professionals mentioned some new factors during the interviews which weren't part of the theoretical model based on literature. Looking at the ranking from the patients some of those new factors have an important influence on successful rehabilitating with a myoelectric prosthesis, according to the patients. Based on the patient ranking some of the in the interview new mentioned factors should be taken into account in the rehabilitation trainings program.

The suggestion that patients should have the possibility to try different prosthetic options before deciding for a prosthesis type scored very high in the patients' pairwise comparisons. The option of trying different prosthesis types can be part of the solution to prevent patients from creating wrong expectations about the myoelectric prosthesis. Like mentioned before, looking at the literature and both the patients' and the health care professionals' ranking, these expectations are the most important factor for a successful rehabilitation.

Another factor which was new added after the interviews with health care professionals and scored high in the patient questionnaire is the suggestion that there should be a regular measurement of the patient's progress in using the myoelectric prosthesis. A patient's motivation is very important for a successful rehabilitation according to the literature (Lovely et al., 1990) and health care professionals. Measuring and showing the patient the progress could help keep the patient motivated.

Focusing the rehabilitation training on a patient's occupation is a suggestion which could have a large influence on successful rehabilitation according to the patients. Upper limb amputation does not need to be a barrier for employment. Research by Milstein et al. (1986) and Datta et al. (2004) show that respectively 89% and 73% of the amputees returned to work after an upper limb amputation, but some needed to chance jobs due to the amputation. Literature shows that the occupational status of the patient correlates with the use of prosthetic upper limbs. Patients with a (fulltime) job are more likely to successfully use their prosthetic arm. (Biddiss et al, 2007A; Roeschlein et al.,1989) The literature doesn't show the effect of the job type on the successful rehabilitation with a myoelectric prosthesis. One of the interviewed health care professionals mentioned that patients with a physical job often don't choose to wear a myoelectric prosthesis because this prosthesis type is more vulnerable than the other prosthesis options. Literature does show a correlation between the educational level of patients and the successful rehabilitation with a myoelectric prosthesis. Patients with higher learning capacities are more likely to successful use their myoelectric prosthesis. (Bouwsema et al., 2010; Roeschlein et al., 1989; Hrnack et al., 2009). Patients with lower learning capacities are more likely to have more physical jobs compared to higher educated patients. Probably the correlation between the educational capacities of a patient and the successful use of the myoelectric prosthesis is partly caused by the difference in job type. Besides focusing the rehabilitation training on how the patient can use the prosthesis while working, it could also be helpful to discuss whether and how the patient can use the myoelectric prosthesis in his or her occupation when choosing a prosthesis type.

Although the interviewed health care professionals have very little experience with rehabilitation for a myoelectric prosthesis using games or virtual reality, they are very interested in the possibilities this has.

Different authors describe the use of games in training with a myoelectric prosthesis which aren't used commercially (jet). Lovely et al. (1990) describe a myoelectric training system which uses a game which is based on a pointer ('gun sight') with which the patient should shoot targets ('enemy spacecraft'). Armiger et al. (2008) developed an interface for the commercial video game Guitar Hero III. Oppenheim et al. (2010) developed an interface for the commercial Wii game control using EMG. Different authors describe myoelectric training systems using virtual reality which also aren't use in the Dutch rehabilitation centers. (Dupont et al., 1994; Lamounier et al., 2010; Takeuchi et al., 2007)

Literature shows some advantages using games and virtual reality in the rehabilitation with a myoelectric arm prosthesis:

- Lovely et al. (1990) states that game provide four motivational requirements which have been shown to be necessary for the learning process as described by Malone (1981).

    a. Challenge. The goal of the game is not too difficult and not too easy to accomplish.
    b. Fantasy. The game is fun to play.
    c. Curiosity. The curiosity is stimulated by audio and visual feedback
    d. Control. The user has control over the game elements.
- Problems such as weight, heat and pain should not contribute to an already hard task of learning to control the myoelectric prosthesis. The virtual simulation is a possible tool to help the users during the difficult initial stages of learning to use a myoelectric prosthesis. (Lamounier et al, 2010)
- A virtual reality training offers a more naturalistic or 'real-life' environment. The stimulus presentation and response measurement can be controlled. A virtual reality can be used for a safe assessment of hazardous situations. It offers increased generalization of learning, and increased standardization of rehabilitation protocols. A virtual reality training increases user participation. (Schultheis et al., 2001)

While the literature and interviewed health care professionals see a lot of advantaged using games and virtual reality in the rehabilitation the patients ranked the possibilities of using these techniques as not having a large influence on successful rehabilitation. Also the possibility to train at home using games or virtual reality scored low in the patient ranking. Possible reasons for that is that patients don't see that much advantages of training with games or virtual reality. Or maybe it is hard for patients to imagine training with these techniques because they are not familiar with it.

Recommendations

Based on the results the following recommendations can be given.
The results of this research shows that the expectancies the patients have of the myoelectric prosthesis is the most important factor which influences successful rehabilitation. Health care professionals need to make sure the patient has the right expectations before the decision is made.

- Give the patients accurate and realistic information in an early stage to prevent the patients from constructing wrong expectations.
- Offering the patient the option of trying different options before making a decision can make sure the patient has the correct expectations of the different prosthetic options.

- More research about how patients form their expectancies can help give the health care professionals insight in the process a patient goes through when choosing a prosthetic option.

Besides factors concerning the expectancy the patients has of the myoelectric prosthesis, some other factors were found that could be improved the successful rehabilitation.

- Regular measurement of the patients' progress and communication of this progress with the patient can help keep the patient motivated.
- A person's occupation is a large part of a persons' daily life. Focusing the rehabilitation on the patients occupation makes sure the patient will use the prosthesis in his or her daily life in the right way, also when working.

Methodological restrains

A limitation in this study is the small patient group that could be recruited for this study. This can largely be explained by the number of patients in the Netherlands. Only 58 people undergo an arm-hand amputation every year in the Netherlands. In our health care professionals sample, the amount of patients treated with a myoelectric prosthesis each year varied from one till five a year. This indicates that only a small group of the 58 patients each year chooses for a myoelectric prosthesis.

11 patients started the questionnaire, 7 patients finished the complete questionnaire. Possible reason for that could be that the questionnaire was quite long. In order to understand how to answer the pairwise comparisons it is necessary to take some time to read the instructions.

When comparing the answers given by the health care professionals with the priorities given by the patients the different methods of asking must be taken into account. Both methods show which factors have a higher influence on the effectiveness of the rehabilitation process then others, but health care professionals scored all factors from 1 to 5 and the patients pairwise compared the factors within one category on a nine points scale. Although the scores of the health care professionals are standardized into relative importance, this different method makes that the standardized relative importance of the health care professionals are closer together. Besides that, the health care professionals mentioned some new factors in the interviews which were added in the patient questionnaires. Because of that some categories contained more factors in the patient questionnaires compared to factors which were scored by the health care professionals. This makes comparing the relative importance between patients and health care professionals difficult.

This study points out factors which influence the success of the rehabilitation program with a myoelectric prosthesis according to patients and health care professionals. The chosen research method results in a priority list of factors, without considering whether the factors should be positive or negative to improve the success of the rehabilitation.

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APPENDIX A: SEARCH STRATEGY LITERATURE SEARCH

For the literature search, the Scopus database was used.
The search started using Scopus with the following search strategies.

- TITLE-ABS-KEY-AUTH**(upper limb prosthe* rehabilitation),** Results 343
- TITLE-ABS-KEY-AUTH**(upper limb prosthe* training)**, results 161
- TITLE-ABS-KEY-AUTH(**upper limb myoelectric training**), results 64
- TITLE-ABS-KEY-AUTH**(upper limb myoelectric rehabilitation)**, results 65

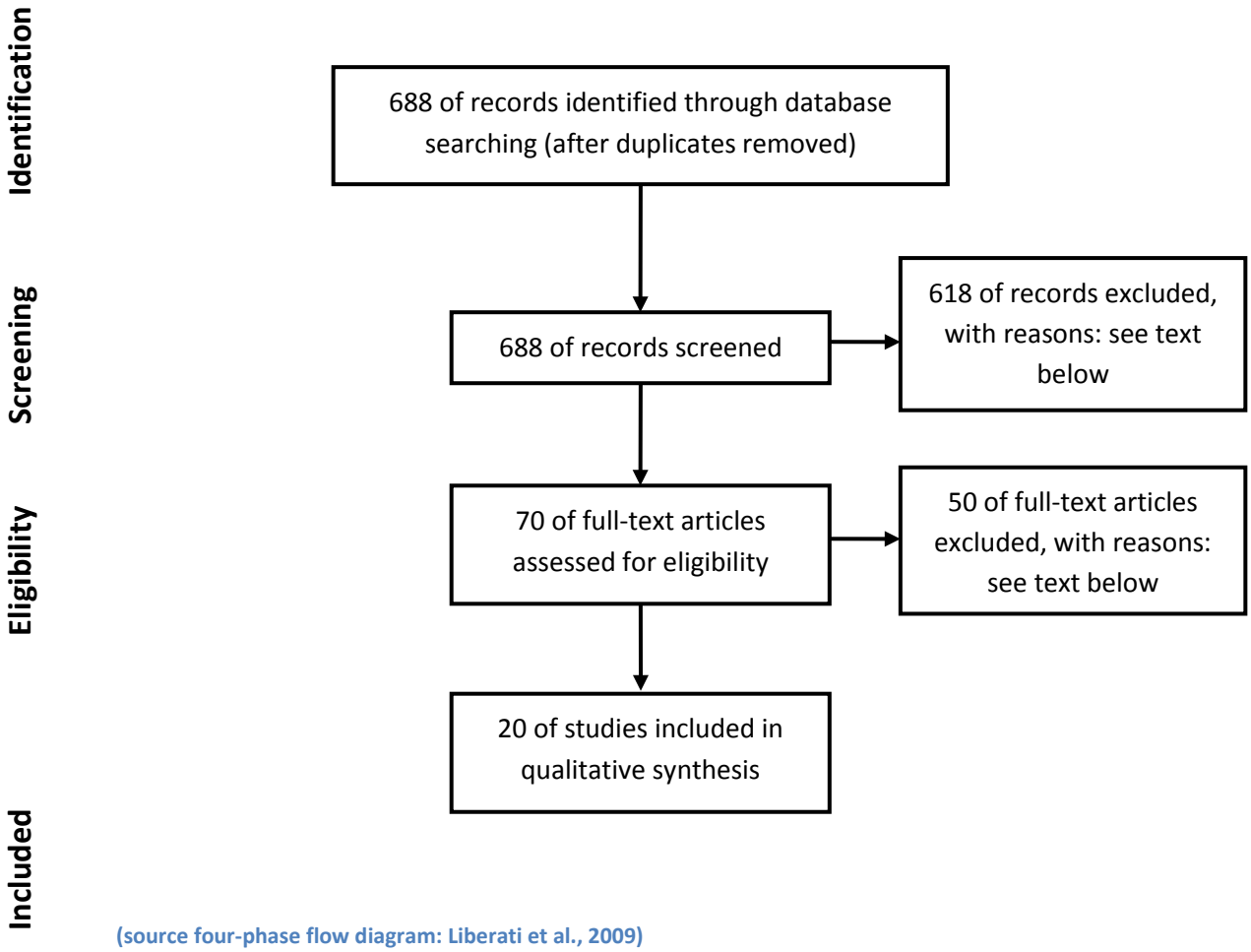
After duplicates removed: 443

- TITLE-ABS-KEY-AUTH(**upper limb prosthe* virtual**), results 50
- TITLE-ABS-KEY-AUTH(**prosthe* training virtual**), results 104
- TITLE-ABS-KEY-AUTH(**prosthe* rehabilitation virtual**), results 90

After duplicates removed: 191

- TITLE-ABS-KEY-AUTH(**upper limb prosthe* training adherence**), results 0
- TITLE-ABS-KEY-AUTH(**upper limb prosthe* training compliance**), results 2
- TITLE-ABS-KEY-AUTH(**upper limb prosthe* rehabilitation adherence**), results 0
- TITLE-ABS-KEY-AUTH(**upper limb prosthe* rehabilitation compliance**), results 8
- TITLE-ABS-KEY-AUTH(**upper limb prosthe* adherence**), results 2
- TITLE-ABS-KEY-AUTH(**upper limb prosthe* compliance**), results 19
- TITLE-ABS-KEY-AUTH(**upper limb training adherence**), results 8
- TITLE-ABS-KEY-AUTH(**upper limb training compliance**), results 33
- TITLE-ABS-KEY-AUTH(**upper limb rehabilitation compliance**), results 53
- TITLE-ABS-KEY-AUTH(**upper limb rehabilitation adherence**), results 9

After duplicates removed: 88



(source four-phase flow diagram: Liberati et al., 2009)

688 records were screened based on title and abstract. 618 of these articles were excluded with the following reasons:

- Article describes only technical aspects of the myoelectric prosthesis or the EMG signals: 94
- Article describes only computer technical aspects of (virtual reality) training system: 13
- Article is concerning not-myoelectric upper limb prosthesis: 69
- Article is not concerning amputation or prosthetic use, but describes other medical conditions like brain injury, stroke, spinal cord injury, paralyzed patients, muscular injuries or functional impairments: 279
- Article is concerning lower limb amputation or prosthesis: 39
- Article describes additional aspects of upper limb amputation like phantom pain, costs, functional testing scales, co-morbidities (mostly case studies) or sports after amputation: 81
- Article describes surgical technique: 29
- Article describes other application of virtual environment: 14

70 full text articles were red for eligibility. 20 articles were used to identify aspect relating to successful rehabilitation and use of the prosthesis. 50 articles were excluded with the following reasons:

- Article describes only technical aspects of the myoelectric prosthesis or the EMG signals: 6

- Article describes only computer technical aspects of (virtual reality) training system: 13
- Article is concerning not-myoelectric upper limb prosthesis: 1
- Article gives description of prosthesis and/or training option without pointing out aspects which may result in high compliance: 27
- Article describes aspect of learning not directly related to prosthetic training: 1
- Article isn't concerning the target population: 1
- Article describes functionality research, not aspects which result in high functionality: 1

APPENDIX B: LIST OF ALL THE ATTRIBUTES USED AND THEIR CLARIFICATION

Factors	**Clarification**
Performance expectancy	*The results the patient expects from following the rehabilitation therapy and using the myoelectric prosthesis*
1. Perceived need of the prosthesis in daily life	The perceived need the for the prosthesis in daily life experienced by the patient
2. Accurate expectations on prosthesis use in daily life	The accuracy of the expectations the patient has of using the prosthesis in daily life
3. Realistic expectations on prosthesis use in daily life	Whether the patient has realistic expectations of using the prosthesis in daily life
Effort expectancy	*The effort it takes to complete the rehabilitation therapy and to control the prosthesis*
4. Difficulty of the training	The difficulty of following the complete rehabilitation therapy
5. The training meets the expectations of the patients	Whether the expectations the patient has of following the rehabilitation therapy corresponds to the actual rehabilitation therapy
6. Time and complexity of the training session	The time and complexity that needs to be invested by the patient each trainings session
7. Total training time	The total training time the patient has to invest by following the complete rehabilitation therapy
8. The patient has insight in the goal and course of the training	Whether the patient has insight in and understands the goal and course of the rehabilitation therapy
9. Training more times a week for faster rehabilitation	When training more times a week the overall rehabilitation therapy can be shortened
10. Regular measurements of the patients progress	Regular measurements of the patients progress during the rehabilitation therapy so the patient can see his or her own progress
11. Focussing the training on a patients occupation	Focusing (a part of) the rehabilitation therapy on how the patient can use the prosthesis in his or her occupation
12. The possibility of training with computer games or VR at the rehabilitation centre	Offering the patient the possibility of training with games or virtual reality in the rehabilitation centre guided by the therapist
13. The possibility of training with computer games or VR at home	Offering the patient the possibility of training with games or virtual reality at home
Social influence	*Perception of the people surrounding the patient about following the rehabilitation therapy and using a myoelectric prosthesis*
14. Support from the social environment of the patient (partner, close family, friends)	Mental en physical support from the social environment of the patient
15. Support from the medical environment of the patient (therapists, doctors, nurses)	Mental en physical support from the medical environment of the patient
16. The extent to which the patient is feeling different in social interactions causes by the amputation	The amputation can make the patient feel different from other people and in social interactions
17. The extent to which the patient is feeling different in social interactions causes by the prosthesis	The prosthesis can make the patient feel different from other people and in social interactions
Structure trainings program	*Factors that change the structure of the rehabilitation program.*
18. Fitting time after amputation	The time between the amputation and the first time the patient visits the physician for a myoelectric prosthesis fitting
19. Providing social skill training for dealing with the amputation and prosthesis in social interactions	Providing training to patients about how to deal with the amputation van the prosthesis in social interactions
20. Offering psychological counseling	Offering psychological counseling to patients to help them dealing

	with the amputation and prosthesis
21. Follow-up after finishing the rehabilitation program	Regular follow-up after the rehabilitation therapy is finished to check whether the patient is still using the prosthesis in the right way and to check if there are problems with the prosthesis
22. The patient has a large influence on the decision for the prosthesis type	When deciding the type of prosthesis, instead of the physician deciding for the patient, the patient has a large influence on the decision
23. The opportunity to try different prosthetic options before deciding	Offering patients the opportunity to try different prosthetic options before deciding.
Facilitating conditions	*Conditions which support finishing the therapy and using the myoelectric prosthesis and don't concern the structure of the rehabilitation program*
24. Funding of the costs for the prosthesis and training	Offering the patient funding by the health care insurance so the patient doesn't have to pay for the prosthesis of rehabilitation
25. (Technical) aspects of the prosthesis	Technical aspects of the prosthesis like its functionality and shortcomings
26. Communication between patients and prosthetists	The frequency and quality of the communication between patients and the rehabilitation physicians and therapists
27. One or a view specialized rehabilitation centers	One or a view rehabilitation centers in the Netherlands where they treat a larger group of patients and by that have more experiences with the small patient group
28. Many rehabilitation centers nearby patients	Many rehabilitation centers in the Netherlands were this patient group can be treated so that all patients can rehabilitate nearby
Moderating factors	*Patient characteristics which influence upper limb prosthetic use, which can't be influenced by the rehabilitation therapy*
29. The age of the patient	The patients age
30. The gender of the patient	The patients gender
31. Earlier positive experiences with prostheses	Whether the patient has earlier positive experiences with wearing a prosthesis and rehabilitating with a prosthesis
32. Earlier negative experiences with prostheses	Whether the patient has earlier negative experiences with wearing a prosthesis and rehabilitating with a prosthesis
33. The occupational status of the patient	Whether the patient has a job
34. Educational and learning aspects of the patient	The learning capability and intelligence of the patient
35. Medical aspects of the patient	Medical aspects like the healing progress of the stump and co morbidities
36. A patient's motivation	A patients motivation to follow the rehabilitation therapy and his or her motivation for using the prosthesis

APPENDIX C: QUESTIONS INTERVIEWS WITH HEALTH CARE PROFESSIONALS

Inleidende vragen

Hoeveel patiënten met een armamputatie heeft een afgelopen jaar begeleid?
Hoeveel patiënten hiervan waren nieuwe patiënten?
Hoeveel nieuwe patiënten waren kinderen? En hoeveel nieuwe patiënten waren volwassenen?
Hoeveel nieuwe patiënten hiervan kregen een myoelectrische prothese?
Hoeveel hiervan waren kinderen en hoeveel waren volwassenen?
Hoeveel nieuwe patiënten hiervan kregen een andere soort prothese?
Hoeveel hiervan waren kinderen en hoeveel waren volwassenen?
Hoeveel nieuwe patiënten hiervan kregen geen prothese?
Hoeveel hiervan waren kinderen en hoeveel waren volwassenen?

Gehele revalidatieproces, hoe en door wie. De training plaatsen in de gehele revalidatie

Kunt u kort het gehele revalidatieproces omschrijven vanaf de amputatie tot gebruik van de myoelectrische prothese?
Hoe lang duurt dit proces vanaf amputatie tot gebruik van de myoelectrische prothese in het dagelijks leven?
Wie heeft welke rol in dit proces?
Wat is uw rol in het proces?
Wat zou er verbeterd kunnen worden aan dit proces?

Voorwaarden myoelectrische prothese

Zijn er speciale voorwaarden of redenen om een myoelectrische prothese te adviseren aan patiënten?
Is hiervoor een richtlijn?
Zo nee, hoe wordt dit dan bepaald?
Zo ja, hoe ziet deze richtlijn eruit? (misschien mag ik het zien/meenemen)

Zijn er patiënten die geen myoelectrische prothese willen?
Wat zijn hiervoor redenen?

Myoelectric training:
- Signal training
- Control training
- Functional training
- Prosthetic recalibration

Kunt u de training met de myoelectrische prothese beschrijven? (gaat het in deze fasen?)
Is de training met de myoelectrische prothese optimaal?
Zo ja, waarom vindt u dit?
Zo nee, wat zou er verbeterd kunnen worden?

Er volgen nu een aantal vragen over het gebruik van games en het gebruik van virtual reality bij de training met een myoelectrische prothese.
Met games bedoel ik het gebruik van computerspellen die aangestuurd kunnen worden door myoelectrische signalen.
Met virtual reality bedoel het weergeven van een virtuele arm of prothese die aangestuurd wordt door myoelectrische signalen.
Is het verschil duidelijk?

Mogelijkheden van games in training

Gebruikt u games bij de training?
En zo ja, in welke vorm?
Wat zijn sterke punten van het gebruiken van games?
Wat zijn minpunten van het gebruik van games?
Op welke manier zou u in een ideale situatie gebruik willen maken van games binnen de training?

Gebruik en mogelijkheden van virtual reality in training

Maakt u gebruik van een virtuele trainingsomgeving?
Zo ja, op welke manier?
Wat zijn volgens u sterke punten van een virtueel training?
Wat zijn bezwaren voor virtueel trainen?
Hoe zou u in een ideale situatie virtuele omgeving willen gebruiken in een training?

Gevolgen van training op therapietrouw en gebruik van de myoelectrische prothese

Stoppen er wel eens patiënten gedurende het huidige trainingstraject?
Zo ja, in welke fase van de training stoppen patiënten?
Om welke redenen stoppen patiënten?

Blijven patiënten die de training afmaken hun prothese gebruiken?
Zo ja, denkt u dat de huidige vorm van training hieraan bijdraagt?
Zo nee, zou de training uiteindelijk gebruik van de prothese kunnen bevorderen?
Hoe zou de training aangepast kunnen worden om het uiteindelijke gebruik van de prothese te bevorderen?

Belang in de literatuur gevonden factoren voor het succesvol volgen van de training en het gebruiken van de myoelectrische prothese. Kan een trainingsopzet deze factoren verbeteren. En welke factoren missen er.

Welke van de onderstaande factoren zijn het meest van invloed op het succesvol volgen van de training en het succesvol gebruiken van de myoelectrische prothese?
Hoe zou de trainingsopzet dit kunnen verbeteren?

Welke factoren zijn nog meer van belang voor het succesvol volgen van de revalidatietraining en het succesvol gebruiken van de myoelectrische prothese?
Hoe zou de trainingsopzet dit kunnen verbeteren?

Afsluitende vraag:
Heeft u nog aanvullingen, of wilt u iets toevoegen over onderwerpen die nu niet aan de orde zijn geweest?

Zou u kunnen aangeven wat voor invloed deze factoren hebben op het succesvol volgen van de revalidatietraining en het succesvol gebruiken van de myoelectrische prothese?

	Helemaal geen invloed --- Heel grote invloed				
De meerwaarde van de prothese voor de patiënt in het dagelijks leven	1	2	3	4	5
Accurate informatie over het gebruik van de myoelectrische prothese in het dagelijks leven	1	2	3	4	5
Realistische verwachtingen over het gebruik van de myoelectrische prothese in het dagelijks leven	1	2	3	4	5
Moeilijkheidsgraad van de training	1	2	3	4	5
De mate waarin de training aansluit bij de vaardigheden van de patiënt	1	2	3	4	5
Te investeren tijd per trainingssessie en de moeilijkheid van de trainingssessie	1	2	3	4	5
De totale duur van de training	1	2	3	4	5
Tijd tussen amputatie en eerste aanmeting met de myoelectrische prothese	1	2	3	4	5
De training sluit aan bij de verwachtingen patiënt	1	2	3	4	5
De patiënt heeft inzicht in het doel en verloop van de training	1	2	3	4	5
De manier waarop de training is opgebouwd	1	2	3	4	5
Het aanbieden van training waarin de patiënt leert hoe om te gaan met de amputatie en prothese in sociale interacties	1	2	3	4	5
Het aanbieden van psychologische counseling	1	2	3	4	5
Follow-up na afronding van de training	1	2	3	4	5
Vergoeding van de kosten voor de prothese en de revalidatie	1	2	3	4	5
(Technische) aspecten prothese	1	2	3	4	5
Communicatie tussen patiënt en therapeut	1	2	3	4	5
De leeftijd van de patiënt	1	2	3	4	5
Het geslacht van de patiënt	1	2	3	4	5
Eerdere positieve ervaringen met prothesen	1	2	3	4	5
Eerdere negatieve ervaringen met prothesen	1	2	3	4	5
Invloed op het keuzeproces voor een prothese	1	2	3	4	5
De werksituatie van de patiënt	1	2	3	4	5
Hoogst genoten opleiding en leercapaciteiten patiënt	1	2	3	4	5
De aanwezigheid van comorbiditeit en andere gezondheidszorgen	1	2	3	4	5
Ondersteuning van de sociale omgeving van de patiënt (partner, directe familie, vrienden)	1	2	3	4	5
Ondersteuning van de medische omgeving (therapeuten, artsen, verpleegkundigen)	1	2	3	4	5
De motivatie van de patiënt	1	2	3	4	5
De mate waarin de patiënt zich door de amputatie anders voelt in sociale interacties	1	2	3	4	5
De mate waarin de patiënt zich door de prothese anders voelt in sociale interacties	1	2	3	4	5