

The added value
of telemedicine services
for physical rehabilitation

Stephanie Jansen - Kosterink

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for physical rehabilitation***

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CHAPTER 1

General introduction



In 1906 the Dutch physiologist Willem Einthoven transmitted Electrocardiograph (ECG) – signals over telephone lines to inspect ECG-signals from patients residing in the Hospital from his laboratory located 1,5 km from the Hospital [1]. This experiment showed the concept of telemedicine for the first time. However, its implementation in daily clinical practice started much later, in the 1920s, when physicians were linked by radio to ships over sea to assist in medical emergencies [2].

The American Thomas Bird was probably the one who first introduced the term telemedicine in the 1970s to describe the process of utilization of telecommunication technologies for examination of patients at a distance [3]. “Healing at a distance” is the literal translation of the term telemedicine. Since then, many other definitions for telemedicine emerged [4]. The European Commission’s Health care telematics program defines telemedicine as “a rapid access to shared and remote medical expertise by means of telecommunications and information technologies, no matter where the patient or relevant information is located”. And, according to the Dutch Technical Appointment (NTA) telemedicine is defined as a process in (health) care, meeting at least the following two features; (1) distance is bridged by using Information and Communication Technology (ICT) and (2) there are at least two persons involved and at least one of them is a registered healthcare professional or acts on behalf of an registered healthcare professional (NEN 8028:2011 nl).

At the end of the 20th century a new area of telemedicine was introduced; telerehabilitation [5, 6]. In this area, services not only consist of the ability to collect, communicate and store relevant medical information but also consist of technology and protocol, describing how physical rehabilitation supervised at a distance can be carried out. In other words, whereas telemedicine in general is more focused on diagnostics and monitoring, telerehabilitation is more focused on remotely supervised treatment. The first telerehabilitation services aimed to deliver healthcare to under-served areas [7]. Nowadays, in the setting of an ageing community and escalation costs of institutional care, there is an economic imperative to restrain healthcare costs [8] by the use of telerehabilitation.

It is generally acknowledged that telerehabilitation has a number of potential advantages in comparison with traditional treatment [5, 9, 10]. Firstly, it can increase the accessibility of healthcare; by implementing telemedicine services in physical rehabilitation. Barriers of time and space disappear and healthcare becomes available for a large group of patients [2, 11]. Telerehabilitation services enable these patients to train independently of a healthcare professional or treatment facilities and provide them the opportunity to train in their own environment under high intensity and supervised by a healthcare professional [9]. Telerehabilitation also has the potential to increase the quality of healthcare. Evidence based medicine is easily integrated in telemedicine services to provide automatic gathering of relevant data on outcome and use of the services. This greatly facilitates objective comparison of treatments and data mining to obtain rules concerning who can profit from which treatment. In addition, telemedicine has the potential to lower healthcare costs. For instance, telerehabilitation enable healthcare professionals to remote consultations, which saves travel time for both healthcare professionals and patients [12-14]. Despite this great potential, implementation of

telemedicine services for physical rehabilitation in daily clinical practice is very limited and most services fade away after a project or pilot phase [15-17]. One of the determinants that is hypothesized to be related to this, is the lack of convincing evidence, showing a treatment supported by technology it is as good as a traditional treatment and that it is cost-effective [9, 10, 16, 18-20]. For healthcare professionals, policy makers and insurance companies, convincing studies into effectiveness of telemedicine service are essential to decide and start implementation.

However, a proper clinical evaluation of telemedicine services is very challenging [9, 10, 18]. In healthcare large prospective randomized controlled trials (RCT's) are considered the gold standard for evaluating the safety and effectiveness of medical interventions. Concerning the effectiveness of telemedicine services for physical rehabilitation various studies and reviews [9, 10, 19, 20] have been performed showing a consistent trend that telemedicine for physical rehabilitation might be effective. Among these studies, the number of studies with (randomized selected) control groups is small. A reason for this might be that the characteristics of an RCT do not match well with the evaluation of telemedicine services. An argument for this is that RCT's are taking a considerable period of time while concurrent technologies are rapidly evolving. It takes time to prepare and execute a RCT with sufficient power and this sets a hold on the technological development with the consequence that at the beginning of the trial the technology is new and at the end of the trial the technology is outdated. Another argument is that most telemedicine services are evaluated as stand-alone services and not implemented into daily clinical practice. This also hampers good insight in the potential value of telemedicine services as these are often shaped by interaction of the end users with the technology. Meaning that services should be evaluated in the way they are implemented into daily clinical practice. This offers a second challenge because the implementation of a telemedicine service often has considerable organisational impacts especially when implemented as partial replacement. For example, the logistics of therapists and therapy rooms that will be differently available once telemedicine is being implemented. Clinical practice shows that it is difficult for clinical centres to maintain a conventional way of working next to the new technology supported program. As a consequence, conventional physical rehabilitation program and a control group is often not available [21]. Given these issues it is currently acknowledged among experts that there is an urgent need for other study designs to adequately evaluate telemedicine services for physical rehabilitation [9, 16, 18, 19].

Looking at the studies performed within the added value of telemedicine services it appears that outcome mostly focuses on clinical outcome and user satisfaction whereas only a small part of the evaluation studies focus on cost related outcome [9, 10, 18, 19]. Despite the fact that these results are promising it does not contribute to the understanding of the underlying processes of the efficiency and effectiveness of these services, such as the actual use of telemedicine services by healthcare professionals and patients [9, 18, 19]. This is however considered important as with face-to-face physical rehabilitation there is increasing evidence that intensive programs are more effective than programs with a lower level of intensity [22]. In face-to-face physical rehabilitation, healthcare professionals are aware of the intensity of the patient's rehabilitation program and when necessary, the healthcare professionals can directly interfere to motivate their

patients to increase their intensity of training, which is less feasible with telemedicine services. In contrast, telemedicine puts the patients in the driver seat, enabling them to train independently of a healthcare professional or treatment facilities with an intensity they choose themselves.

So far, research focusing on the use of telemedicine services is mostly limited to the intention of end-users to use the service [23] and only a few studies addressed the actual use of a telemedicine service for physical rehabilitation [24, 25]. However telemedicine services often have the advantage that objective information about the actual use of the telemedicine service is logged and as such the intensity of the patient's rehabilitation program can be objectively assessed. This data can be exploited to identify the underlying mechanisms that generate the effectiveness of a telemedicine service for physical rehabilitation [26]. The next step is to focus on the actual use of telemedicine service and the association between actual use and clinical benefit.

Outline of thesis

The aim of this thesis is to contribute to knowledge concerning the added value of telemedicine services for physical rehabilitation. The first part of this thesis focuses on the state of the art evaluation of two telemedicine services; a myofeedback-based telerehabilitation service and an exercise-based telerehabilitation service. The clinical evaluation with multiple endpoints (access, clinical, costs [27]) of the myofeedback-based telerehabilitation service is described in chapter 2. This telemedicine service is evaluated as a stand-alone service and the exercise-based telerehabilitation service is evaluated as a partial replacement of a face to face physical rehabilitation program. The outcome of the clinical evaluation of this service is described in chapter 3. Chapter 4 aims to give a state of the art of telemedicine for remote physical rehabilitation, presenting an overview of the technology that is currently used in telemedicine, the clinical purposes for which it is used as well as the way it is delivered to the patients (service configuration).

The second part of the thesis focuses on the actual use of previously evaluated telemedicine services, first steps to identify the underlying mechanisms that generate the effectiveness of a telemedicine service for physical. In Chapter 5 the association between patient satisfaction, compliance and clinical benefits for the myofeedback-based telerehabilitation is investigated. In chapter 6 the actual use and the association between actual use and clinical benefits of the exercise-based telerehabilitation service evaluated as a partial replacement of face to face physical rehabilitation is described. Because of the hypothesized association between use and clinical benefit, it becomes important to motivate patients to use the telemedicine service sufficiently. To enhance the use of the service, gaming technology is of interest as it distracts patients from their complaints [28] and makes exercising fun [29]. An example of gaming technology, the Playmancer exergame, is addressed in chapter 7. Finally, chapter 8 presents a general discussion on the added value of telemedicine service for physical rehabilitation.

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CHAPTER 2

*The clinical effectiveness of a myofeedback-based teletreatment service
a randomized controlled trial*

Kosterink SM, Huis in 't Veld MHA,
Cagnie B, Hasenbring M,
Vollenbroek-Hutten MMR.
Journal of Telemedicine and Telecare.
2010;16(6):316-21.



in patients with nonspecific neck and shoulder pain:

Summary

We investigated the effectiveness and efficiency of a four-week myofeedback based teletreatment service in subjects with non-specific neck and shoulder pain. Subjects were recruited in Belgium, Germany and the Netherlands and randomly allocated to the intervention or conventional care. Subjects in the intervention group received four weeks of myofeedback training. Pain intensity and disability were evaluated by questionnaires prior to the intervention (baseline), immediately after four weeks of intervention (T0) and at three (T3) months follow-up. To investigate efficiency, the time-investment of both therapists and patients were assessed. Seventy-one subjects were included in the study (36 in the intervention group and 35 in the conventional care group). Myofeedback based teletreatment was at least as effective clinically as conventional care. Pain intensity and disability decreased after 4 weeks of intervention for both groups and part of the effect remained at 3 months follow up. The teletreatment also increased efficiency for therapists by almost 20% and patients experienced the benefits of less travel time and travel costs by remote consultation. Myofeedback based teletreatment and has the potential to ensure more efficient treatment for patients with non-specific neck and shoulder pain.

Introduction

Neck and shoulder pain is becoming increasingly common. With a self-reported point prevalence of 21% for neck pain and also 21% for shoulder pain, it is one of the most common musculoskeletal complaints.[1] The aetiology is not always obvious and 63-87% [2,3] of the complaints can be labelled non-specific.[4] Most patients with neck and shoulder pain recover spontaneously within a few weeks, but a significant proportion (30-40%) develop persistent pain and may seek treatment [1] Neck and shoulder pain is most commonly treated by physiotherapy [5] which focuses on increasing the strength of the neck and shoulder muscles, improving posture and/or increasing the mobility of the neck. In patients with chronic non-specific neck pain, physiotherapy has a positive effect, but the effect is small [6,7]. A relatively new treatment for neck and shoulder pain is the myofeedback-based teletreatment service (MyoTel).

This telemedicine intervention can be expected to improve the quality of care because it is applied with much higher intensity than can be provided in conventional, face to face treatment. Also the treatment is provided in the subject's own environment which facilitates the learning of a variety of work tasks and activities of daily living. Second, because of the availability of patient data on a server, myofeedback therapists will be better able to prepare and conduct counselling sessions. Consequently, the geographical region in which subjects can be treated by telemedicine is unlimited which will improve accessibility. Third, remote counselling is less time-consuming for the patient because of reduced travel time, and so the treatment should be cost-saving.

The literature offers limited evidence for the benefits of telemedicine and appropriate evaluation of telemedicine is still considered challenging. DeChant et al. [8] proposed a framework for telemedicine evaluation in which the type of assessment is tailored to the development life cycle of the technology. This so-called staged approach differentiates between telemedicine evaluation at application (stage 1-2) and global levels (stage 3-4). Evaluation of a telemedicine application starts with an evaluation of the technical efficacy (accuracy and reliability) of the application and evaluation of the primary objective of the service in terms of access, quality or cost (stage 1-2). During the subsequent deployment a comprehensive evaluation is necessary, using multiple endpoints such as quality, accessibility and cost of care (stage 3). The last step of evaluating a telemedicine service is to examine whether the overall evaluation of a technology in one system, applies in other settings (stage 4)[8].

For the MyoTel intervention, a stage 1-2 evaluation has been conducted by Huis in 't Veld et al. (2008) [9]. In this pilot study 10 women suffering from work related neck and shoulder pain received the MyoTel treatment [9]. They used the system for 4 weeks during their daily activities. There was a beneficial effect on perceived pain intensity and disability. After 4 weeks of treatment 80% of the subjects reported a clinically-relevant reduction in pain intensity and 50% of the subjects reported a clinically-relevant reduction in pain disability.

The next step in the staged approach is a large scale evaluation with multiple outcome measures (stage 3-4 evaluation). Thus the research question of the present study is

whether the effectiveness (pain intensity and disability) and efficiency (time-investment) of a four-week MyoTel intervention is similar to that of conventional practice in subjects with non-specific neck and shoulder pain.

Methods

Subjects were recruited in Belgium, Germany and the Netherlands between March 2008 and March 2009. Patients were recruited by rehabilitation centres, advertisements in newspapers, patient associations and web forums. The therapists approached candidates by telephone to inform them about the treatment in more detail. Volunteers received a screening questionnaire, which was used to evaluate the inclusion and exclusion criteria. Subjects with non-specific neck and shoulder pain were included if they were female, aged 20-60 years, had their complaints for a period of at least three months, at least 7 days during the last month and an average pain score of at least 3.0 on a 10 cm visual-analogue scale (VAS). People with a specific disorder (except patients with a whiplash-associated disorder) or a general pain syndrome were excluded. Subjects were also excluded if their complaints were work-related, they used muscle relaxants, were obese (body mass index >30 kg/m²) or had insufficient understanding of the language spoken during treatment. The power calculation, based on the results of the pilot study [9], indicated that at least 27 subjects should be included in each group. Block randomization was used to assign subjects to either a MyoTel or a conventional care group. The study was approved by the appropriate ethics committee. All participants gave their informed consent prior to participation.

Intervention group. Subjects in the intervention group received 4 weeks of MyoTel. The myofeedback training is based on the Cinderella hypothesis [10], which was deduced from earlier findings by Henneman et al. [11], showing that the motor units of a given muscle are recruited in a fixed order. Small, low threshold motor units are recruited at low levels of contraction, before larger ones, and kept activated until complete relaxation of the muscle. Long-lasting activation of these units may cause degenerative processes, damage and pain [12].

MyoTel [9] consists of a garment with incorporated dry surface electrodes. The electrodes continuously record the upper trapezium muscle activation patterns. If there is insufficient muscle relaxation, the processing unit connected to the garment, vibrates and creates a soft sound. The processing unit is connected by a Bluetooth link to a personal digital assistant (PDA) and from this PDA the surface electromyography (sEMG) data are sent to a server via a wireless connection. The server is remotely accessible by the therapist. The remote counselling sessions between therapist and patient are based on the sEMG data but also on information from a diary about activities and a mood questionnaire (Locally Experienced Discomfort) which are kept by the patients during treatment.

Patients with neck and shoulder pain were taught about personal work style in relation to muscle tension and learned simple techniques to manage actual stressors at work and at home that might affect their musculoskeletal health. Face-to-face consultations took place in the first and last week of the MyoTel treatment. During treatment the therapists kept a log in which they noted the time required per patient.

Conventional care group. Subjects in the conventional care group did not receive any specific intervention and continued their conventional care, such as medication (pain

killers), physiotherapy, acupuncture, osteopathy, chiropractice, ergonomic counselling, stress management and relaxation training. At baseline, 76% of the conventional care group had received treatment for their neck and shoulder pain in the previous month.

Measurements

The main clinical outcomes were pain and disability. Subjects were asked to rate their level of pain during the previous week. Pain intensity was assessed on a VAS [13,14]. The VAS consisted of a 10 cm horizontal line with “no pain at all” at the left and “as much pain as possible” at the right extremity of the line. The psychometric properties of the VAS have been shown to be sufficient [15]

The level of disability was assessed with the Pain Disability Index (PDI), a self-rating scale that measures the effect of pain on the ability to participate in life and activities [16]. The PDI contains 7 items: (1) family and home responsibilities; (2) sport and leisure activities; (3) social activities; (4) activities partly or directly related to working; (5) sexual behaviour; (6) self-care; (7) daily activities. Answers were provided on an 11-point scale with “not disabled” and “fully disabled” at the extremes. The psychometric properties of the PDI have been shown to be satisfactory in a chronic pain population [16].

These measurements were performed prior to the intervention (Baseline), immediately after 4 weeks of intervention (T0) and at 3 months follow-up (T3).

The main resource utilization outcomes were the therapist time required and the travel time saved per remote consultation of the patient. The total travel time saved per remote consultation was asked in a questionnaire at T0 of all subjects in the intervention group.

Statistical analysis

Analysis was performed using standard software (SPSS version 11.5). The normality of variables was evaluated by the Kolmogorov-Smirnov test. Descriptive statistics (mean and SD) were calculated for all socio-demographic variables.

The PDI score is a sum score of 7 items. Multiple imputation was used to estimate the missing PDI items based on the other observed variables of the total research population and on the relations between all variables in the total research population. At T3, questionnaires were posted to both the subjects of the intervention and the control groups. If the responses of these questionnaire at T3 was less than 70%, the primary outcome (pain intensity and disability) was estimated using multiple imputation. Missing VAS and PDI (at T3) items for the non-responders was imputed based on the other observed variables of the total research population and on the relations between all variables in the total research population [17].

Short and long term effectiveness between the two groups on pain intensity and disability were investigated by using a mixed-model analysis for repeated measures. Time of measurement (Baseline, T0 and T3) was used as a within-subjects factor and type of intervention (intervention and conventional practice) as a between-subjects factor. Post hoc comparisons were made when required and Sidak adjustments were used to correct for multiple tests.

For the pain intensity in the neck and shoulder region and the disability level, the percentage of subjects with a clinically relevant improvement between Baseline and T0 were assessed. For the VAS a change of 1.3 cm on a 10 cm VAS was considered to

be clinically significant [13]. For the PDI a change of 7 units was defined as a clinically relevant change [18].

Results

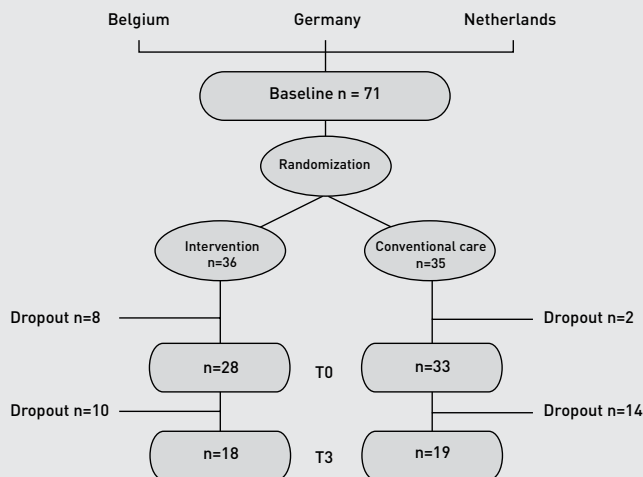
Seventy-one subjects with non-specific neck and shoulder pain were included in the study. There were 36 subjects in the intervention group and 35 in the conventional care group. Twenty-five subjects were recruited in Belgium, 15 in Germany and 31 in the Netherlands. Of the 71 subjects, 61 subjects completed the four weeks of study. Eight subjects in the intervention group and 2 subjects in the conventional care group dropped out. The main reason for drop out in the intervention group was failure of the MyoTel technology, whereas the main reason in the conventional care group was lack of motivation.

The two groups were similar in age, weight and height at the time of recruitment ($p \geq 0.21$). The mean age was 39.9 years (SD 12.4) in the intervention group and 37.6 years (SD 9.9) in the conventional care group. The mean height and weight were 170.9 cm (SD 6.7) and 65.6 kg (SD 10.) in the intervention group and 169.3 cm (SD 6.5) and 68.7 kg (SD 9.1) in the conventional care group.

In the intervention group 85% of the subjects were employed, 7% were employed but on sick leave compared to 55% employed in the conventional care group and 30% on sick leave. These percentages were significantly different ($p = 0.04$). In the intervention group 57% of the subjects had suffered from an accident related injury (e.g. whiplash-associated disorder) compared to 64% in the conventional care group, but these percentages were not significantly different ($p = 0.55$).

At T0, 39% of the intervention group and 33% of the conventional care group had received physiotherapy for their neck and shoulder pain during the previous month. At T3 these percentages decreased to 12% of the intervention group and 26% of the conventional care group. No significant difference in percentage of receiving physiotherapy between both groups were found ($p \geq 0.24$).

Figure 1. Flow chart for subject recruitment, randomization and drop-outs



The number of subjects at Baseline, T0, and T3 and the number of drop-outs are shown in Figure 1. The subjects who dropped-out did not differ in age, weight, height, VAS or PDI scores from those who completed the intervention ($P \geq 0.09$). The response of the T3 questionnaire was 61% meaning the primary outcomes (pain intensity and disability) at T3 were imputed.

Clinical effectiveness

Analysis at group level

Figure 2 shows the mean VAS scores in the neck and shoulder region for the two groups. For the intervention group there was a clear decrease at T0 (1.2 cm), and T3 (1.7 cm) compared to Baseline. For the conventional care group there was a decrease at T0 (1.4 cm) compared with Baseline, but at T3 there was an increase compared with T0 (0.4 cm). Mixed-model analysis for repeated measures showed that pain intensity in the neck and shoulder region changed significantly over time ($p \leq 0.001$) but without additional effects for the type of treatment ($p > 0.34$).

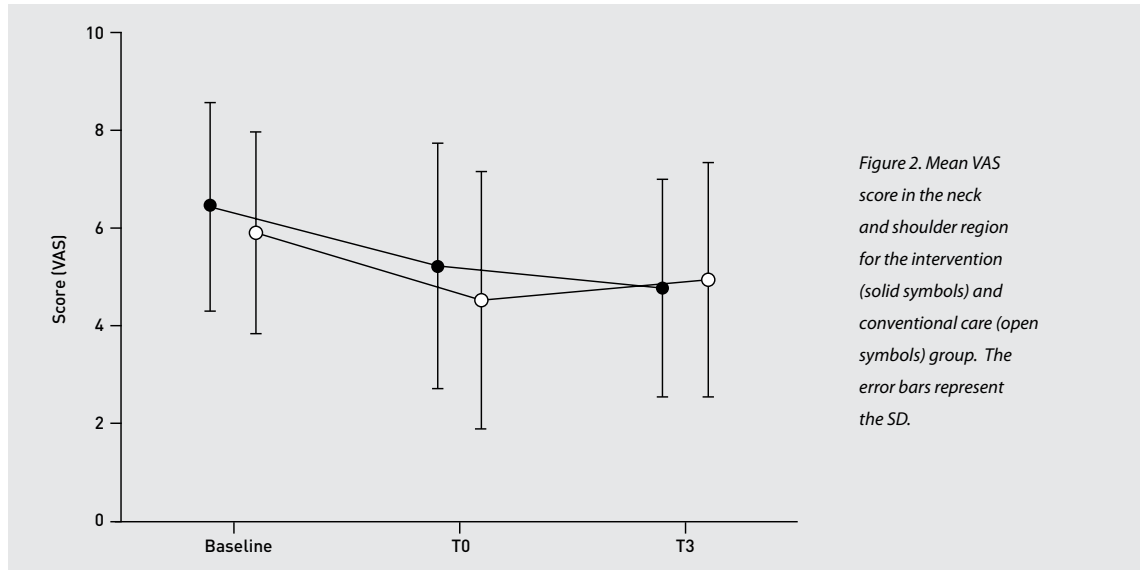
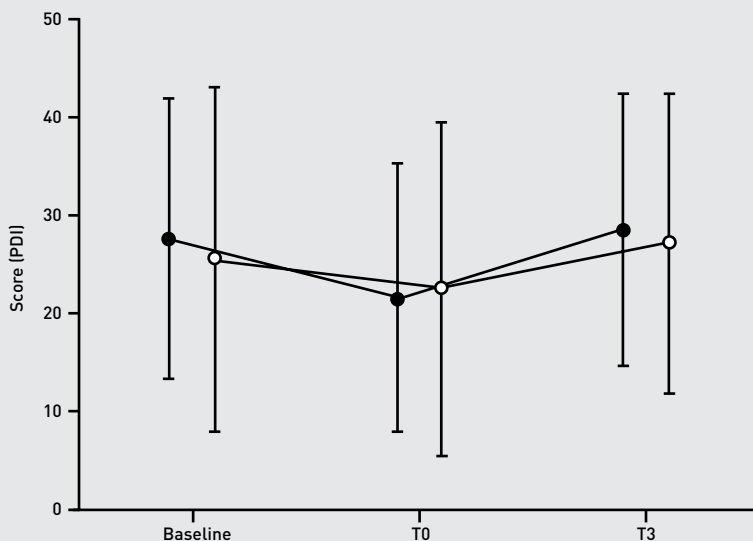


Figure 2. Mean VAS score in the neck and shoulder region for the intervention (solid symbols) and conventional care (open symbols) group. The error bars represent the SD.

Figure 3 shows the mean PDI scores for the two groups. For the intervention group a clear decrease was observed at T0 (6.0 units) but at T3 there was an increase compared with T0. For the conventional care group there was a decrease at T0 (3.0 units) compared with baseline but there was also an increase compared with T0 at T3.

Mixed-model analysis for repeated measures showed that disability in the neck and shoulder region changed significantly over time ($p \leq 0.01$) again without additional effects for the type of treatment ($p > 0.11$).

Figure 3. Mean PDI score for the intervention (solid symbols) and conventional care (open symbols) group. The error bars represent the SD.



Analysis at the individual level

Immediately after the intervention period 39% of the intervention group showed clinically relevant improvement on pain intensity. At 3-month follow-up this percentage slightly decreased, see Table 1. After 4 weeks of intervention 36% of the intervention group showed a clinically relevant improvement in disability. This proportion declined after three months follow up.

Table 1. Percentage of subjects showing clinically relevant improvement in VAS and PDI scores at T0 and T3 (compared to Baseline) for the two groups. There were no significant differences between the groups ($p \geq 0.24$)

	Improvement at T0		Improvement at T3	
	VAS	PDI	VAS	PDI
Intervention	39%	36%	39%	13%
Conventional care	46%	32%	32%	29%

Time investment

Figure 4 shows the average weekly therapist time (preparation and consulting) per patient. The dotted line in Figure 4 is the average duration of treatment received by subjects per week the past month for their neck and shoulder pain of the total research population at baseline; 62.6 (SD 71.7) min (n=36). Four myofeedback therapists logged the treatment time per week per patient of the 28 patients. The average time of the first face-to-face consultation was 70.0 (SD 23.0) min; preparation took 18.8 (SD 13.4) min and the duration of the actual face-to-face consultation was 51.3 (SD 17.5) min. The average time of three teleconsultations was 37.3 (SD 20.4) min; preparation took 15.6 (SD 10.2) min and the duration of the actual teleconsultation was 21.8 (SD 12.3) min. The average time of the last face-to-face consultation was 59.3 (SD 20.7) min; preparation took 13.7 (SD 8.8) min and the duration of the actual face-to-face consultation was 45.6 (SD 19.2)

min. Twenty-four of the 28 subjects in the intervention group completed a questionnaire about the total travel time they saved per remote consultation. Figure 5 shows the saved travel time by category. Fifty percent of the subjects had a travel time by care or public transport of 30 min or less. Twenty-one percent of the subjects had a travel time of 30-60 min, whereas 29% of the subject had a travel time of 60 min or more. The average distance subjects needed to cover in order to receive the teleconsultation in the clinic was 51.3 (SD 66.3) km.

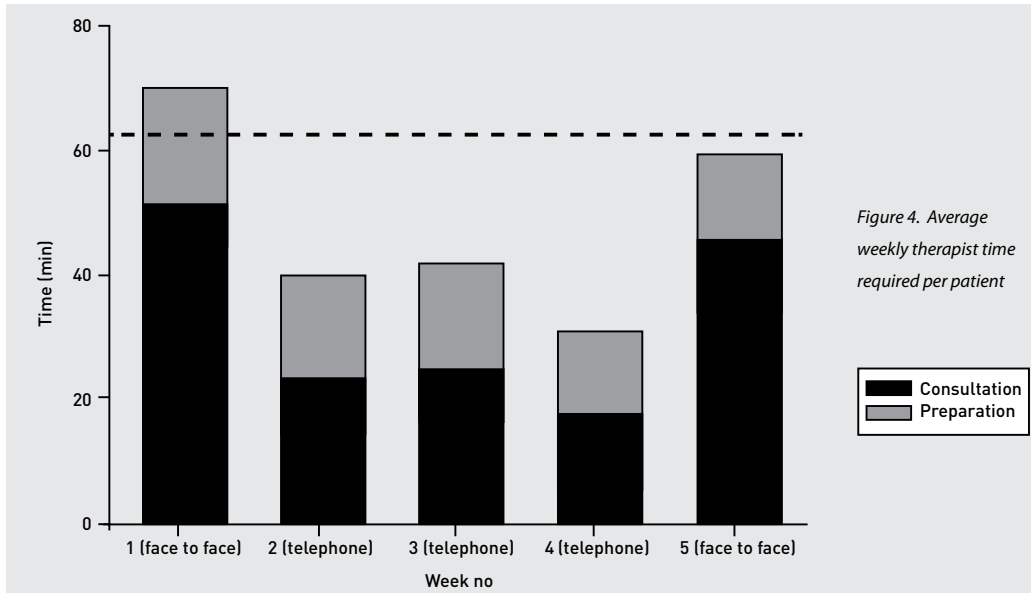


Figure 4. Average weekly therapist time required per patient

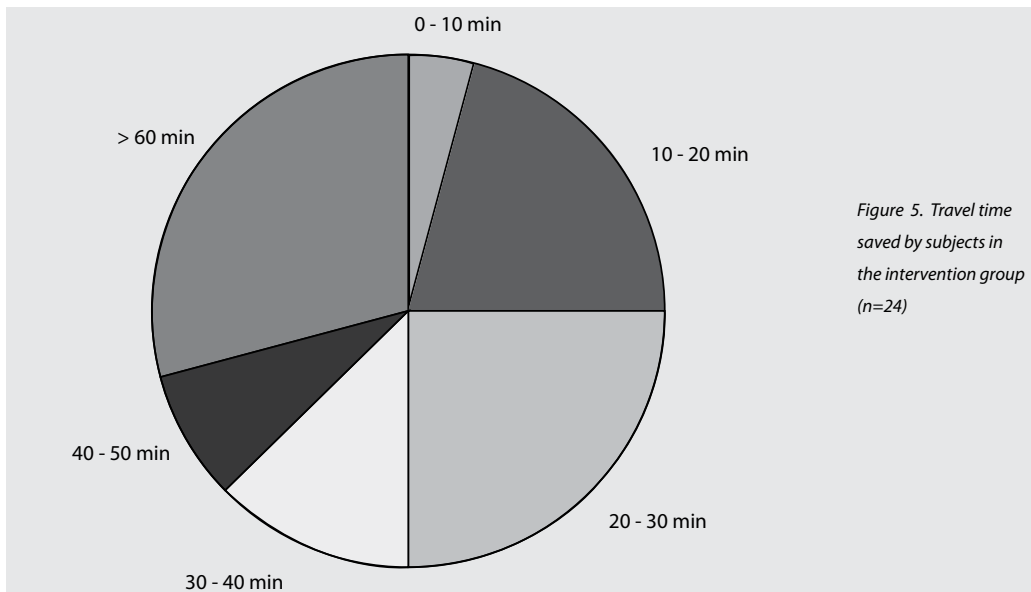


Figure 5. Travel time saved by subjects in the intervention group (n=24)

Discussion

The present study showed that both treatments were effective in reducing pain intensity and disability level, and there were no significant differences between the groups. At 3 month follow up the effect on pain intensity in both patient groups remained, but the disability scores in both groups returned to baseline. These results are in line with the results of Voerman et al. [18] who investigated the effects of an ambulant but not remote myofeedback treatment, including ergonomic counselling compared to ergonomic counselling alone, on work-related neck and shoulder pain and disability. They also concluded that pain intensity and disability were significantly reduced after both interventions and that no significant differences were observed between the two intervention groups [18].

There was a beneficial effect of MyoTel on both perceived pain intensity and disability in almost 40% of the patients. With respect to the pilot study [9] the percentages found in this study are much lower. Huis in 't Veld et al. [9] found that 80% of the patients had a clinical improvement on pain intensity and 50% of the patient on disability. An explanation for these differences might be the different pathology of the subjects (non-specific vs. work-related neck and shoulder pain) and/or the small sample size in the study of Huis in 't Veld et al. (n=10). In addition, Huis in 't Veld et al. used another outcome measure for disability, i.e. the Neck Disability Index (NDI)[20] instead of the PDI. The switch to the PDI was based on the completeness of the PDI. It is assumed that the NDI does not represent the full spectrum of disability experienced [21], since it assesses only some items (working, driving, sleeping) [20]. The PDI measures the impact of pain on the ability to participate in life and activities more generally [16].

The percentage of clinically relevant improvement found in this study is more in line with the results of Voerman et al. [18] who investigated the effect of an ambulant but not remote myofeedback treatment including ergonomic counselling on work-related neck and shoulder pain and disability. About 45% of the patients showed clinically relevant improvement in pain intensity and/or disability (measured by PDI). This means that the effectiveness of remote myofeedback (MyoTel) did not change by reducing the duration of face-to-face contact between professional and patient.

With regard to the efficiency, the results of the present study show that the average time spent on each patient for a 4 week MyoTel course (2 face-to-face consultations and 3 remote consultations) was 4.2 h (SD 1.2). Compared to conventional care this is a reduction of almost 1 hour (20%). The reduction of treatment time was most obvious during the remote consultation (week 2, 3 and 4). During these weeks it would almost be possible for a therapist to treat two patients instead of one within the same time. The patients also experienced increased efficiency by remote consultation. Half of the patients in the MyoTel group saved 30 min or less travel per remote consultation. The other half of the patients saved 30 min or more per remote consultation. This reduction in travel time was also beneficial in reducing fuel costs. In addition, this efficiency of patient's travel time was beneficial to the patients' employers.

MyoTel is developed and first evaluated in the Netherlands. According to the Stage

Approach of DeChant et al., [8] the last step (stage 4) of a comprehensive evaluation of a telemedicine service is to examine whether the overall evaluation of a technology in one system applies in other settings. During the present study MyoTel was evaluated in two other countries: Belgium and Germany. There were no significant differences in primary outcome between the results in the different countries and the effectiveness and efficiency was equal in the three different health care systems.

A comprehensive evaluation of a new intervention starts with an evaluation of access, quality and cost. The present study focused on quality (effectiveness and efficiency). The cost evaluation is described in a separate paper [22]. Access has not yet been studied, although a benefit of the remote consultations is the reduction of the need for travel.

The power calculation indicated at least 27 patients in each group. Based on this calculation the group sizes at baseline were sufficient. This study was limited by the high rate of drop outs at T0 and especially at T3. The main reason for dropout was failure of the MyoTel technology. Clearly a system with fewer technical failures will be needed for large scale deployment. At T3, 24 dropouts were reported. This high level of dropouts was partly due to sending questionnaires to the patients by post. This could have been avoided by a telephone call introducing the questionnaire or by inviting patients at T3 to the clinic.

In conclusion, MyoTel was clinically at least as effective as conventional care. Pain intensity and disability decreased after 4 weeks of intervention for both groups and a part of the effects remained at 3 months follow up. MyoTel also increased efficiency for therapists by almost 20% and patients experienced the advantage of less travel time and travel costs by remote consultation. Thus MyoTel can be considered a very promising treatment for future health care. It can also be regarded as a telemedicine service that has the potential to ensure a more efficient treatment for patients with non-specific neck and shoulder pain.

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CHAPTER 3

A quasi-experimental study: Facilitating remote physical rehabilitation for patients with a chronic disorder by means of telemedicine.

Abstract:

Introduction: This study involves an evaluation of a telemedicine service implemented as a partial replacement of a physical outpatient rehabilitation program. The telemedicine service is an exercise-based tele-rehabilitation service facilitating remote physical rehabilitation for patients suffering from chronic lower back pain or pulmonary disease.

Materials and Methods: Effectiveness was evaluated in a quasi-experimental study with multiple outcomes on quality (complaints, disability and physical condition) and access (usability, satisfaction and motivational character of the service). The intervention group received an outpatient rehabilitation program in which telemedicine was used as partial replacement of face to face care. Instead of 3 visits per week to the clinic as is being carried out in conventional care, patients visited the outpatient rehabilitation clinic for 2 days and they were instructed to exercise at least 1 day in their own environment using the exercise-based tele-rehabilitation service. The control group received the conventional rehabilitation program.

Results: One hundred and eighteen patients were included in this study: 80 patients in the intervention group and 38 patients in the control group. Both groups equally benefit from the outpatient rehabilitation program. There were no significant differences between the groups. The usability (system usability scale score of 71.2 (SD 15.0; n=47), satisfaction (average rate 6.0 (SD 2.0; n=55), and level of motivation of the exercise-based tele-rehabilitation service were sufficient, but slightly disappointing.

Conclusions: The telemedicine supported the outpatient rehabilitation program as partial replacement of face to face care was as effective as the conventional outpatient rehabilitation program.

Introduction

The population of western countries is ageing. In Europe the proportion of people aged 65 or older is forecast to increase from 14% in 2010 to 25% in 2050 [1]. As the risk of chronic diseases increases with age [2], an increase in the number of patients with a chronic disorder is expected. To comply with the associated increase in the demand of care, technology supported interventions giving patients the opportunity to rehabilitate in their own environment, are starting to appear in healthcare. This potential only counts however, when these innovations are at least a partial replacement of face-to-face care. In this way they enable the needed reduction in time that is needed for a healthcare professional for each individual patient [3].

The in the CLEAR (Clinical Leading Environment for the Assessment of protocols in home care, ICT-PSP CLEAR 224985) project, a technology supported intervention, and an exercise-based tele-rehabilitation service, is designed and implemented as partial replacement of a 3 day outpatient group multidisciplinary rehabilitation program (RP) for patients with chronic lower back pain (CLBP) or pulmonary disease (PD). This service makes use of a notebook with webcam and consists of two treatment modules. Module one contains a database of exercise videos. Module two, a teleconference service, facilitates contact between patient and the healthcare professional. With these modules, the professional remotely compose an individual tailored exercise program and supervise the patient. As real-time contact is not necessary, patients carry out the program independently on a self-scheduled time in their own environment which fits in the current trend of patients' self-management [4].

Previous studies evaluated telemedicine services with comparable functionalities. These services are suitable to facilitate remote physical rehabilitation [5-8]. Patients are able to use the technology, are satisfied with the technology and experienced clinical benefits by using these services [5-8]. The outcomes of these studies are relevant. However in none of these studies the telemedicine service is evaluated as a partial replacement of traditional face-to-face care. Therefore the true potential of telemedicine is still unknown [9]. To the authors' knowledge, an evaluation of an exercise-based tele-rehabilitation intervention implemented as a partial replacement into a physical RP has not been published so far. These types of evaluation are needed to convince the various stakeholders in healthcare of the true potential of telemedicine and as such the ability to accelerate its implementation [10, 11].

This study involves an evaluation study of a telemedicine service facilitating remote physical rehabilitation for CLBP or PD patients implemented as a partial replacement into an outpatient RP. For this evaluation the proposed framework of Dechant et al, 1996 [12] is adopted. Within this framework the type of assessment is tailored to the development life cycle of the technology and differentiates between telemedicine evaluation at application (stage 1-2) and global levels (stage 3-4). In the first stages the outcomes used are focused on, whereas in later stages a comprehensive evaluation using multiple endpoints such as access, quality and costs are applied. Following this framework, this study also assesses multiple outcomes. Outcomes in this study are related to quality and access of the service. It is our hypothesis that the quality of care remains equal by

replacing one day at the rehabilitation clinic by one day at home. Considering access it is our hypothesis that the satisfaction, usability and the motivational character of the service are important prerequisites and need to be judged at least as sufficient.

Materials and Methods

Patients were recruited between October 2009 and December 2011, by Roessingh Center for Rehabilitation, Enschede, The Netherlands. Patients referred by their rehabilitation physician to the RP for CLBP or COPD between October 2009 and May 2010 (eight months) were asked to participate in the control group (CG). CLBP and COPD patients referred to the physical outpatient RP between June 2010 and December 2011 (19 months) were asked to participate in the intervention group (IG).

The inclusion criteria used during the intake of patient for the RP for CLBP were (1) chronic non-specific pain (>3 months), (2) motivated and (3) a psychoneurotic score < 150 (Symptom checklist (SCL-90) [13]). The inclusion criteria used during the intake of patient for the RP for PD were (1) pulmonary diseases, (2) motivated and (3) non-smoking. Patients included in this study had sufficient understanding of the Dutch language and were aged above 18 years.

The power calculation, based on the results of a comparable tele-rehabilitation service [14, 15], indicated that at least 26 patients with CLBP and 32 patients with PD should be included in each group. The appropriate ethics committee approved the study. All patients gave their informed consent prior to participation.

Design

The design is a quasi-experimental design; a number of patients will receive the conventional RP and a number of patients will receive the exercise-based tele-rehabilitation service as partial replacement of the conventional RP. This design was chosen from a feasibility perspective. Implementation of the exercise-based tele-rehabilitation service as partial replacement of the conventional RP had organisational impact on the planning of the program especially on the availability of professionals and

Figure 1: exercise-based tele-rehabilitation service for chronic patients



treatment rooms. As a consequence, when implemented the conventional RP was not available anymore at Roessingh Center for Rehabilitation. As such the control group was included in the period before the telemedicine intervention was implemented.

Intervention group (IG)

This group received the exercise-based tele-rehabilitation service as partial replacement of the conventional RP. During the first 2 weeks (for CLPB) or 4 weeks (for COPD) the patient visited the clinic for 3 days and received, next to their RP, training (1 hour per week) on how to use the exercise-based tele-rehabilitation service (figure 1). From the third (for CLBP) or fifth (for COPD) week on, the tele-rehabilitation service was delivered to the patients as partial replacement; 1 day at the clinic was replaced by 1 day rehabilitation in their own environment. With the exercise-based tele-rehabilitation service, the therapist composes remotely a weekly individual tailored exercise program for each patient. Every week the patient had the option to record an exercise with a webcam. The recorded exercises were assessed by the therapist. Patient and therapist contacted each other weekly by teleconference or would meet each other during the remaining 2 days to discuss the rehabilitation progress.

Depending on holidays the program lasted 7 weeks for the CLBP patient and 12 weeks for the PD patient in total and as such the tele-rehabilitation service was used for 5-8 weeks.

Control group (CG)

The control group received the conventional RP. Patients visited the clinic three times a week. Depending on holidays the program lasted 7 weeks for the CLBP patient and 12 weeks for the COPD patient.

Measurements

The outcome on quality focuses on complaints (pain or dyspnea), disability and physical condition, considering the determinants of the ICF model [17]. Complaints and disability were assessed pre-test (in the first week of the outpatient rehabilitation program), post-test (in the last week of the outpatient rehabilitation program) and at follow-up 2 months later (T2), the physical condition was assessed pre-test and post-test. Outcome on access focuses on usability, satisfaction and the motivational character of the services and were assessed post-test.

Patients were asked to rate their level of pain for CLBP patients and level of dyspnoea for PD patients during the previous week. Level of pain and dyspnoea were assessed on a visual analogue scale (VAS) [18, 19]. The psychometric properties of the VAS is sufficient [20].

Roland Disability Questionnaire (RDQ): disability of the CLBP patients was assessed with the RDQ [21]. This questionnaire is an illness-specific 24-item functional assessment questionnaire that is frequently used for back pain. The RDQ has established validity, reliability and responsiveness to change [22]. The Dutch version [23] of the RDQ is used. Chronic Respiratory Disease Questionnaire (CRQ): the CRQ is a widely used instrument in pulmonary rehabilitation. CRQ is an interviewer administered questionnaire, which asks patients to rate their health status (physical and emotional) in four domains: dyspnoea,

fatigue, emotional function, and mastery [24]. The Dutch translation of the CRQ is used [25].

Åstrand ergometer bicycle test: the test was used to assess the physical condition of the CLBP patient [26]. This sub maximal test, in which patients bicycle for six minutes at a certain intensity, is not valid for measuring maximal oxygen intake, but is for determining its progress. With the output of the test (workload and heart rate), the VO₂max (corrected for gender, age, length and fat free mass) can easily be estimated with the Åstrand-Ryhming-nomogram.

The Six-minute walk test (6MWT): The 6MWT was used to assess the physical condition of the PD patients [16]. The objective of this test is to walk as far as possible for 6 minutes on flat ground. During the test, patients were permitted to slow down, to stop, and to rest when necessary.

Concerning the accessibility of the exercise-based tele-rehabilitation service the usability was assessed with the System Usability Scale (SUS) [17]. The SUS presented ten statements about the perceived usability of the service. The SUS score ranges from 0 to 100 (low and high usability, respectively). At the start of this study no validated and reliable satisfaction questionnaire was available [18, 19] therefore the patients satisfaction with the exercise-based tele-rehabilitation service was assessed with a question to rate the service on a scale from 0 to 10 (low and high satisfaction, respectively) and a question whether a patient would recommend the service to another patient. Since the aim of the service was to motivate patients to rehabilitate in their own environment, the level of motivation was assessed by two questions. The first question, patients rated on a 7-Likert scale with “demotivating” and “motivating” at the extremes, the level of motivation related to the exercise-based tele-rehabilitation service. The second question was answered with yes or no: “Did the exercise-based tele-rehabilitation service motivate you to perform your exercises?”

Statistical analysis

Analysis was performed using standard software (SPSS version 20.0). The normality of variables was evaluated by the Kolmogorov-Smirnov test. Descriptive statistics (means and SD) were calculated for all social-demographic variables. Regarding satisfaction, usability and level of motivation, the mean scores of the questionnaires were calculated. At follow-up, questionnaires were sent to both the subjects of the intervention group and the control group. If less than 90% the response of the patients responded on these questionnaires the clinical outcomes were estimated using multiple imputation. Based on the other observed variables of the total research population and on the relations between all variables in the total research population this estimation is made. Multiple imputation [20] is an established method for dealing with missing data. Estimates obtained with multiple imputed data were shown to be valid.

For health outcome the pooled outcome (means and standard error of mean (SEM)) after imputation were shown (only for the patient who had completed the program). Short and long term effectiveness between the two groups on physical condition, disability and complaints were investigated by using independent t-tests and mixed-model analysis

for repeated measures. Time of measurement (pre-test, post-test and T2) was used as a within-patients factor and type of intervention (intervention and control group) as a between-patients factor. Post hoc comparisons were made when required and Sidak adjustments were used to correct for multiple tests. Significance levels were set at $p < 0.05$.

Results

One hundred and eighteen patients were included in this study: 68 CLBP patients 50 PD patients. The IG consists of 80 patients (44 CLBP and 36 PD patients) and the control group of 38 patients (24 CLBP and 14 PD patients). Of the 118 patients, 101 patients completed their RP; 64 patient of the IG (35 CLBP and 29 PD patients) and 37 patients of the CG (24 CLBP and 13 PD patients). Sixteen patients of the IG withdrew. The main reason for withdrawal was an early end of their RP due to health related exacerbation ($n=7$), technical problems with the equipment ($n=4$) or personal circumstances, such as lack of time or motivation ($n=5$). One patient of the CG withdrew. This patient had to finish the RP due to health related exacerbation. There is no explanation for the high number of health related exacerbation in the IG. However, it is very unlikely that this is caused by use of the exercise-based tele-rehabilitation service as this service does not change the content of the RP but only changes the way in which it is provided to the patient. Home based in stead of clinic based. The variables appeared as normally distributed. At the time of the recruitment, both groups were similar in gender, age, height, weight, gender and employment ($p \geq 0.053$) (table 1).

Figure 2 shows the number of patients at pre-test, post-test and T2 as well as the number of withdrawals. The patients who withdrew did not differ in gender, age, weight, height, complaints, disability or physical conditions from those who completed the intervention ($p \geq 0.076$). Of the clinical outcome 13.3% of the values were missing at random. Therefore, the missing values at pre-test, post-test and 2 month follow-up were imputed.

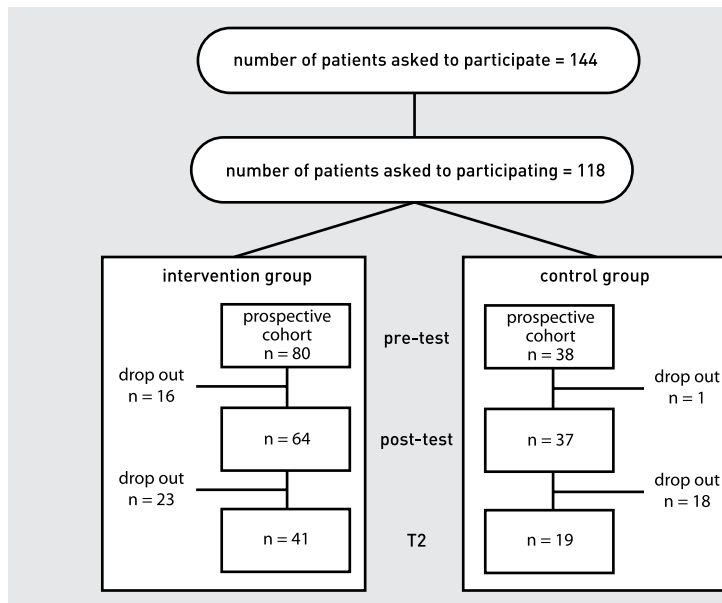


Figure 2: flow chart for patient recruitment and dropouts

Table 1: demographic characteristics at baseline

	CLBP patients		PD patients	
	IG (n=44)	CG (n=24)	IG (n=36)	CG (n=14)
Age in years	43.4 (SD 11.6)	43.5 (SD 13.7)	54.8 (SD 10.3)	53.8 (SD 10.7)
Height in cm	177.7 (SD 10.9)	173.7 (SD 10.6)	177.5 (SD 10.4)	177.6 (SD 11.4)
Weight in kg	87.9 (SD 20.2)	78.0 (SD 12.5)	86.3 (SD 18.5)	82.8 (SD 18.9)
Gender	59% male	42% male	61% male	64% male
Employed	73%	83%	47%	50%

Complaints

For the CLBP and PD patients in both groups the scores on pain intensity and dyspnoea decreased (figure 3). Mixed-model analysis for repeated measures showed that these scores changed significantly over time ($p \leq 0.001$) but without additional effects for the type of treatment ($p \geq 0.070$).

For the CLBP patient post-test 70% of the IG showed a clinically relevant improvement on pain intensity versus 43% of the CG ($p \leq 0.015$). For pain intensity a change of 1.3 cm on a 10 cm VAS was considered to be clinically relevant [21].

For the PD patient post-test 38% of the IG showed clinically relevant improvement on dyspnoea versus 54% of the CG ($p \leq 0.139$). For dyspnoea a change of 2.1 cm on a 10 cm VAS was considered to be clinically relevant [22].

Table 2: Mean disability scores for the intervention and control group

	intervention group	control care group	p-value
CLBP			
RDQ - pre-test	12.5 (SEM 0.7; n=35)	10.8 (SEM 1.2; n=24)	0.175
RDQ - post-test	7.4 (SEM 0.8; n=35)	8.1 (SEM 1.2; n=24)	0.566
RDQ - T2	9.0 (SEM 0.7; n=35)	8.0 (SEM 0.8; n=24)	0.308
COPD			
CRQ - pre-test	79.7 (SEM 3.3; n=29)	78.4 (SEM 6.2; n=13)	0.835
CRQ - post-test	94.2 (SEM 3.8; n=29)	98.4 (SEM 5.4; n=13)	0.531

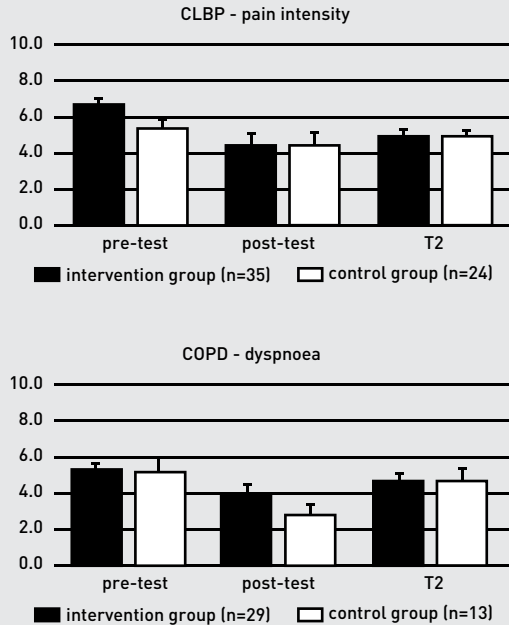


Figure 3: complaints scores for CLBP and COPD patients pre-test, post-test and at 2 months follow-up

Disability

CLBP patient of the IG showed an average decrease of 5 points on the RDQ score from pre-test to post-test, CLBP patients of the CG had an average decrease of 3 points. Mixed-model analysis for repeated measures showed these scores changed significantly over time ($p \leq 0.001$) but without additional effects for the type of treatment ($p \geq 0.091$) (table 2). The sum-score of the CRQ of the PD patient increased with 15 points for the IG and 20 points for the CG, but post-test the CRQ sum scores of both groups were not significantly different ($p \geq 0.531$) (table 2).

Physical condition

The outcome of the Åstrand ergometer bicycle test for the CLBP were in both groups comparable at pre-test and post-test ($p \geq 0.485$). In the IG ($n=35$) the scores pre-test and post-test were 28.1 (SEM 1.8) and 31.8 (SEM 1.9), respectively. For the control group ($n=24$) the scores pre-test and post-test were 30.1 (SEM 1.9) and 32.7 (SEM 2.0), respectively. For the PD patient the pre-test scores on the 6 minute walk test were significantly different ($p=0.005$) between the IG (442 m; SEM 9.5; $n=29$) and CG (458 m; SEM 38.8; $n=13$). Post-test, the walking distance increased with 67 meter for the IG and 83 meter in the CG. Post-test the score were not significantly different between both groups ($p=0.08$) being 509 m (SEM 9.3; $n=29$) for the IG and 458 (SEM 38.75; $n=13$) for the CG.

Usability

Thirteen percent of the patients rate the usability of the exercise-based tele-rehabilitation service as "best imaginable", 4% as "excellent", 38% as "good", 43% as "OK" and only 2% as "poor". On average the usability of the exercise-based tele-rehabilitation service was rated OK (SUS score ≤ 71) [23]. The mean SUS score was 71 (SD 15.9; n=47).

Satisfaction

Two-third of the patients rated the exercise-based tele-rehabilitation service with a 6 or higher on a scale from 0 to 10. The average rate was a 6.0 (SD 2.0; n=55). Thirty-six percent of the patients would recommend the service to another patient, 34% of the patient would not recommend the service to another patient and 30% of the patient gave a neutral answer (n=59).

Level of motivation

Twenty-one percent of the patients stated the exercise-based tele-rehabilitation service to be a motivation to exercise, 33% of the patients stated the service to be demotivating and 46% of the patients gave a neutral answer (n=58). Thirty-nine percent of the patients claimed that the service motivated them to exercise in their own environment.

Discussion

In line with our hypothesis, the quality of care of the RP for patients suffering from a chronic condition remains equal by replacing 1 day at the clinic by 1 day of home rehabilitation, by using an exercise-based tele-rehabilitation service. In both groups there were significant health benefits but there were no significant short-term or long-term differences on health outcome between both groups. IG and CG equally benefit from the outpatient rehabilitation program. Concerning the accessibility of care, patients were able to use the service during the outpatient rehabilitation program. Scores on satisfaction and usability were sufficient but slightly disappointing.

The functionalities of the service were frozen before the evaluation. However during the study various technical issues became evident. In case these affected the usability of the service too much, they were solved and technical adjustments were made. These issues as well as the fact that technology is rapidly evolving may have affected the outcomes on access. Patients considered the technology used as outdated. All suggestions and wishes for technical improvements were collected to improve the service lastly. Both patients and therapists suggested various new functionalities to improve the usability of the service. These suggestions included the wish to receive automatic reminders to comply with their exercise program by short text messages or email and to make the service compatible for smartphone or tablet.

From a feasibility point of view a quasi-experimental design was chosen for this study. There was no randomisation which could result in a selection bias. However the design chosen made feasible to compare the outcome of the intervention group with the outcome of a control group. At the outset both groups were similar on assessed demographic characteristics, but other unknown characteristics could have influenced the effect. The sample size of the intervention groups were, based on the sample size calculation, sufficient. However, well sized controlled groups were difficult to achieve.

One of the key considerations to successful telemedicine services is that these should partially replace, rather than add to, existing ways of working in healthcare [3]. However, most telemedicine services are implemented as follow-up or standalone treatments [9]. Implementation of a technology supported intervention into a conventional healthcare program has organisational impact on the planning of this program. As a consequence, when implemented, the conventional healthcare program is often not available anymore and makes it hard to obtain a valid control group. Besides, technology is rapidly evolving. For these two reasons there is an urgent need to search for other study designs to adequately evaluate telemedicine services. This need is also stressed in a review by Kairy et al., 2009 [11] into tele-rehabilitation for individuals with physical disabilities and a review of reviews by Ekeland et al., 2012 [10] to methodologies for assessing telemedicine. Designs that may be appropriate and take into account the individual variability are single-case designs and factorial designs. These can also be used to identify which component of a telemedicine service is effective [24]. Factorial designs enable a researcher to simultaneously evaluate two interventions and their interaction [25].

For the analysis of this study the patients' adherence to the service were not taken into account. All patients, without knowledge about adherence, were included. Technology supported intervention in rehabilitation gives patients the opportunity to rehabilitate independently from their healthcare professional and as such can increase their rehabilitation intensity. Besides, the intensity of rehabilitation has a positive effect on health outcome [26, 27]. Therefore, further publications about the amount of use of the tele-rehabilitation service and the relation between amount of use and health outcome should be interesting.

An aim of the service was to motivate patients to rehabilitate in their own environment and to execute their exercises at home. This service gave patients access to a database of exercises videos and teleconference service to facilitate contact between patient and therapist. Only a fifth of the patients stated that the service motivated them to exercise. Indicating that these modules were not sufficiently motivating patients to execute their exercises at home over longer periods of time, which is often the necessity in patients with chronic diseases. This means better motivational strategies should be implemented in these services. Potential examples are patient reported outcome measures (PROMs) that give patients insight in their health status over time [28], gaming technology which is hypothesised to distract patients from their complaints [29] and make exercising fun [30] and ambulant technology that allows objective monitoring and feedback during everyday life activities instead of during or in addition to exercise at home [31, 32].

In conclusion, an exercise-based tele-rehabilitation service implemented into an outpatient RP for chronic patients, as partial replacement of face to face care, was as effective as the conventional RP. These findings support the hypothesis that telemedicine has true potential for every day care. However technology is rapidly evolving, continuous improvements to technology are needed to keep the level of satisfaction and usability sufficiency. In addition better motivational strategies will probably increase the patient's motivation and as such the overall satisfaction along side the service.

Acknowledgments

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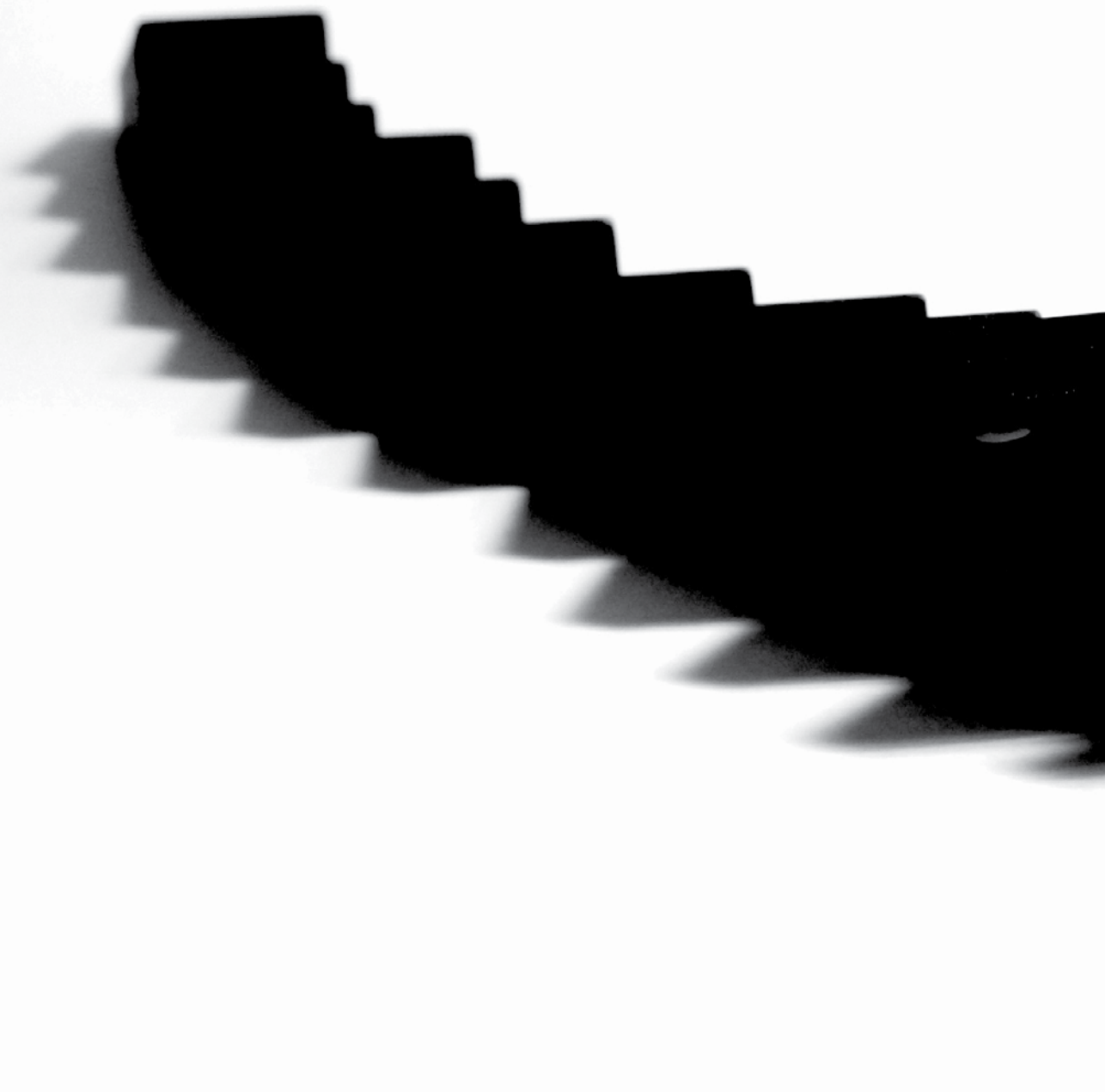
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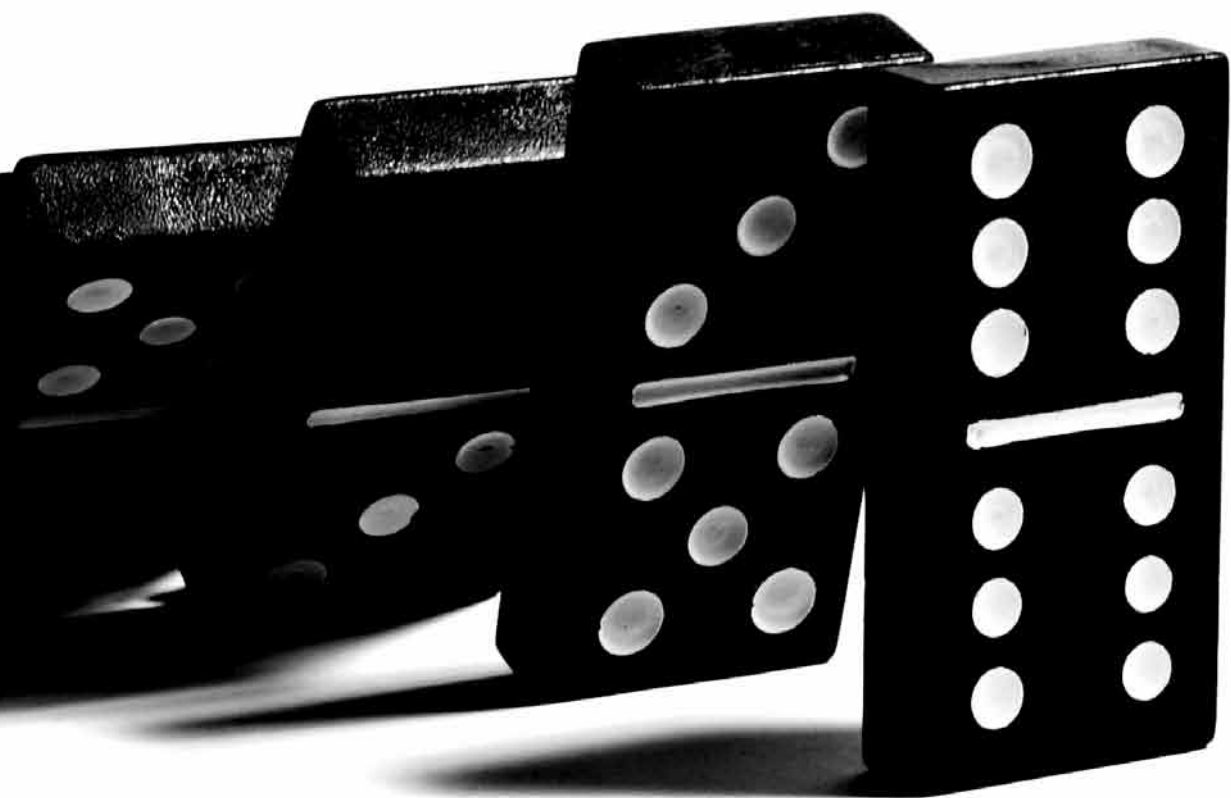
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CHAPTER 4

Why telemedicine does not find its way towards sustainable implementation?





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Cranen K, Hermens HJ & Vollenbroek-
Hutten MMR. Journal of Telemedicine and
application - submitted

Abstract

The aim of this paper is to present an overview of the current state of telemedicine for remote physical rehabilitation by analysing the technology that is used, the clinical purpose for which it is used as well as the way it is delivered to the patients (service configuration). Relevant references were searched by a literature and manual search. After screening, 40 relevant papers were included. Results show a large variability in the technology used as well as its clinical purpose. In 42.5% of the included papers the clinical purpose was remote supervision and exercising. The telemedicine interventions were mostly investigated as autonomous or follow up treatment and never as partial replacement of conventional care. Outcome mainly focuses on satisfaction and on clinical outcome but hardly on cost-effectiveness. In addition, outcome parameters were not properly matched to the expected added value. As such the true potential of telemedicine interventions is still far from known. Future studies should focus more on the evaluation of telemedicine service in the way they will be implemented in every day care. And to contribute to the challenges of rising demand for and costs of health care this implementation should much more focus on implementation as partial replacement of conventional healthcare instead of being an addition.

Introduction

It is widely acknowledged that telemedicine has great potential in healthcare to overcome the problems related to our ageing community, to increase the quality and accessibility of care, and to restrain the economic imperative of rising healthcare costs. Looking at the trajectory to come to successful telemedicine interventions it is known to be a time-consuming iterative process where development starts after a requirement analysis and is followed up with a feasibility study as a first proof of concept. This process is iterative and results in a technical stable application, what is appreciated by the patients and ready for clinical evaluation [1].

The current state of the art shows that the evidence regarding the effectiveness of telemedicine interventions is growing [2, 3]. However even proven effective telemedicine interventions often fade away and are not implemented in healthcare [4-6]. A striking example is our myofeedback-based teletreatment [7]. This teletreatment, that facilitates remote physical rehabilitation for patients suffering from chronic neck and shoulder pain, has shown to be as effective as conventional treatment [8, 9]. Although this intervention has a positive societal business model [10], it is not implemented in healthcare. It deserves a further analysis what factors impede the uptake of these services and what is needed to speed up this implementation [11, 12]. One of the questions directly related to this, is whether the evaluation studies currently being performed provide sufficient evidence to convince healthcare professionals, policy makers and insurance companies.

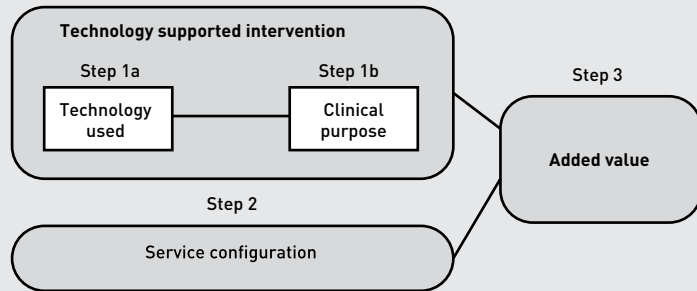
Considering the interventions being investigated there is a large heterogeneity both in the technology used as well as in the clinical purpose the telemedicine intervention is used for [13-16]. These two are however often related and they together identify the added value of telemedicine. For instance to enable a direct contact between the healthcare professional and the patient during treatment a videoconferencing tool is often used. In this case the added value is mainly to increase the accessibility of care and a gain of (travel) time for the patient. In contrast to enable professional coaching of daily functioning other technologies are needed; technology to monitor the patient's daily functioning, technology that allows remote data access and technology to give automatic and professional feedback to the patients. The added value in this case is expected to be again an increase of accessibility of care for both patient and professional but also a more intensive and by this a more effective treatment. From these examples it can be concluded that the added value of telemedicine is dependent of both the technology used and the clinical purpose telemedicine is used for. However to what extent is this taken into account so far?

Next to the technology used and clinical purpose the added value of telemedicine is expected to be dependent on to the way the telemedicine intervention is implemented into healthcare (service configuration). Is it implemented as a partial replacement of the conventional treatment, as an addition to the conventional treatment or as a follow-up treatment? For instance, after a period of outpatient rehabilitation the patient can extend his rehabilitation by using a telemedicine intervention. In this case a follow up treatment is provided and the added value is a more intensive and by this a more effective treatment. When the outpatient rehabilitation program also is partial replaced by a telemedicine intervention the added value is also expected to lower healthcare costs [17]. Although in this case the patient can rehabilitate in his own environment with no demand on the healthcare professional and the treatment facilities. Once having a clear

picture on how the telemedicine interventions will be implemented in healthcare, it is possible to identify whether the intervention has the potential to increase accessibility, to improve the quality of healthcare, and/or to decrease healthcare costs [1]. Therefore, to identify the potential of these interventions they should be evaluated in the same way as they will be implemented into every day healthcare practices [2, 3, 18].

Until now it is insufficiently clear to what extent technology used, clinical purpose and service configuration are taken into account in studies evaluating the added value of telemedicine interventions facilitating remote physical rehabilitation and as it is insufficiently clear to what extent the potential of telemedicine is really investigated. The aim of this paper is to present an overview of the current state of telemedicine for remote physical rehabilitation by analysing the technology that is used, the clinical purpose for which it is used as well as the way it is delivered to the patients. In addition, starting from this categorization the potential added value for various telemedicine services can be identified and will be discussed.

Figure 1: framework to enable conclusions about the potential for future successful implementation of telemedicine services



Methods

Figure 1 presents the research framework of the current paper. The framework allows to categorize technology used (step 1a), clinical purpose (step 1b) and service configuration (step 2) and to identify the potential added value for various telemedicine services (step 3). For the state of the art of “technology supported interventions” and “service configuration” a computerized literature search of the Medline and Scopus databases was conducted in January 2014. The search strategy and keywords used for both databases are shown in Table 1. In addition to this search, the online versions of three journals in telemedicine (Journal of Telemedicine and Telecare, Journal of Telemedicine and e-Health and International Journal of Telemedicine and Applications) were also manually searched for additional relevant references.

<i>For Medline database</i>	
Step 1	teletreatment OR telerehabilitation OR telehealth OR telecare OR ehealth OR telemedicine [MeSH Terms] OR therapy, computer assisted [MeSH Terms] OR ambulatory monitoring [MeSH Terms] OR computer [MeSH Terms] OR Technology [MeSH Terms] OR Internet [MeSH Terms] OR telecommunication [MeSH Terms]
Step 2	physical therapy* OR physiotherapy OR exercise [MeSH Terms] OR physical therapy modalities [MeSH Terms]
Step 3	home OR home based* OR outpatient OR home care services [MeSH Terms]
Step 4	1 AND 2 AND 3
<i>For Scopus database</i>	
Step 1	teletreatment OR telerehabilitation OR telehealth OR telecare OR ehealth OR telemedicine OR computer assisted therapy OR ambulatory monitoring OR telecommunication
Step 2	Physical therapy OR physiotherapy OR exercise
Step 3	home OR outpatient
Step 4	1 AND 2 AND 3

*Table 1: Search Strategy
For Medline database*

Papers were included when: (1) they were designed as an evaluation study of a telemedicine intervention, (2) they concerned patients and not healthy subjects, (3) the telemedicine intervention utilized remote treatment by means of ICT, (4) the treatment focused on physical rehabilitation or exercising and (5) they were written in English, German or Dutch. Papers were excluded when: (1) no outcome of the evaluation was provided, (2) they only gave a description of the telemedicine intervention or the proposed evaluation, (3) no healthcare professionals were involved in the service delivery, (4) they concerned patients with mental illnesses, (5) they were duplicates of other already included paper and (6) they were published before 01-01-2000.

Potential eligibility of the papers was first identified from the titles and abstracts identified during the searches. Two reviewers (CSvdV and SMJK) read all titles and/or abstracts independently. If an abstract did not give sufficient information about the study, the full-text paper was obtained for further review. Then the reviewers evaluated full-text papers independently and reached consensus about whether or not the papers should be included. There was no disagreement among the two reviewers, so the third independent reviewer was not asked to make a final decision. Papers were not blinded for authors and journals.

A data extraction form was used to include details on the included papers concerning population, type of intervention technology used and service configuration. After

assessing all full-text papers, the reviewers reached a consensus about the information and completed the data extraction form.

Step 1a: Technologies used

In literature various classifications on technology used are presented. For this paper the classification of Rogante et al., 2010 [19] is slightly adapted to the further increased potential of ICT the previous years. In more detail:

1. Synchronous communication technologies: a set of technologies allowing synchronous communication among patient and healthcare professional such as telephone, one-on-one chat and videoconference systems;
2. Asynchronous communication technologies: a set of technologies allowing to communicate asynchronous such as, email and messages services;
3. Sensor-based technologies: set of devices allowing for the remote acquisition of relevant parameters mainly related to patient physical performances and used for assessing physical health status;
4. Exercise applications to actuate patient to exercise or rehabilitate, such as web applications or applications for computers or smart phones. These applications are in particular developed for rehabilitative purposes;
5. Virtual reality and gaming technologies: a set of technologies stimulating the patient to execute the requested exercises.

Step 1b: Clinical purpose

The clinical purpose of telemedicine service to facilitate remote physical rehabilitation we identify as the part of the healthcare process which is replaced by using technology. The clinical purpose of a telemedicine service can be for instance to enable remote contact between patient and healthcare professional during treatment or enable professional coaching of daily functioning. Based on the various technology used (step 1b) and the type of intervention the clinical purpose will be identified.

Step 2: Service configurations

No classifications of service configurations are provided in literature. As already addressed in the introduction roughly, telemedicine interventions can be implemented in the healthcare process in three configurations:

- (1) as partial replacement of the conventional treatment
- (2) as addition to the conventional treatment
- (3) as follow-up treatment to the conventional treatment

When a telemedicine intervention is not implemented into the healthcare process, this intervention is considered as an autonomous treatment.

Step 3: Added value

Once the technology used, clinical purpose and service configuration are identified for each individual telemedicine service, its potential added value (step 3) can be defined as well as the outcome measures that are needed and were used to measure this potential. Outcome is expressed in terms of a potential to increase accessibility, to improve the quality of healthcare, and/or to decrease healthcare costs, following DeChant [1].

Results

Based on our literature search, we started with a set of 1511 citations. These were analyzed and 1413 citations were excluded following screening. We retrieved 98 potentially relevant papers in full text. We excluded 62 of these based on the pre-specified inclusion and exclusion criteria. The literature search provided us with 36 papers. The manual search of the online version of the journals in telemedicine by screening of titles, abstracts and full-texts left us with 4 relevant papers in full text. In total, we retrieved 40 relevant papers. The main characteristics of the 40 included papers are presented in Table 3.

Step 1a: Technologies used

Category 1 (synchronous communication technologies): in 24 of the included papers, a videoconference system was used to enable contact among the patient and healthcare professional. These systems were used to have remote face-to-face contact among patient and healthcare professional during exercising [20-35] or a scheduled face-to-face contact [36-43]. Telephone was used in 10 of the included papers. In 1 paper, there was direct telephone contact during exercising [44]. In the remaining papers telephone contact was scheduled on a daily [45] or weekly [8, 9, 46-49] bases. In two papers, contact by telephone was unscheduled and only when necessary [50, 51]. In one paper, the combination of telephone and webcam contact was used for a daily contact among patient and professional [52] and in one paper a chat function was used for a weekly contact among patient and professional [53].

Category 2 (asynchronous communication technologies): in four papers patient and professional had contact by email on a weekly bases [39, 46, 54, 55]. In two papers contact among patient and professional was enabled by asynchronous short messaging technology [56, 57]. These messages were sent after an exercise session.

Category 3 (sensor-based technologies): in 26 papers sensor-based technologies were used for a variety of reasons. In more details:

- a. In eight papers to guarantee secure exercising [35, 42-45, 50, 51, 57]: in five papers patients used an ECG-recorder during their exercise sessions [42, 44, 45, 50, 51], in two papers patients used an pulse oximeter during their exercise sessions [35, 43] and in one paper the patients used before and after an exercise session technology to recorder their ECG [57].
- b. In seven papers to monitor patient's progression or adherence: in six papers the patient used a heart-rate monitor during exercise sessions [46, 49, 53-55] or blood-pressure monitors before and after an exercise session [57] and in one paper patients were asked daily update their health dairy with output form sensor-based technologies [37] to monitor their progression.
- c. In three papers to deliver automatic and professional feedback to the patients [8, 9, 48]: in these related papers EMG of the trapezius muscle was continuously recorded to provide the patient automatic and professional feedback.
- d. In nine papers to detect the quality and quantity of motions of a patient: in six

papers the motions of the patients were detected to assess the quality and quantity of these motions by the healthcare professional [36, 38-41, 52] and in three papers the motions of the patients were used as input for a virtual reality setting [21, 22, 26].

Category 4 (exercise-applications): in 18 papers, exercise-applications are used to actuate patients to perform exercises and to rehabilitate in their own environment. In ten papers, web applications are developed to provide patients, by the internet, access to personal diaries [8, 9, 37, 48, 56], treatment plans [37, 39, 41, 43, 47, 53-56], education models [37, 53] and questionnaires [53, 56]. In six papers patients used a computer application [32, 36, 38, 40, 50, 52], what gave patients access to their treatment plans. In three papers, a telephone application was developed to provide the patient with continues feedback on muscle tension [8, 9, 48].

Category 5 (virtual reality and gaming): in four papers, virtual reality or games technologies are used to stimulating the patient to execute the requested exercises; in combination with a motion tracking system [21, 22, 26] or a functional electrical stimulation (FES) garment [32]. Output of the motion tracking system was used as input for the virtual reality or game.

Step 1b: Clinical purpose

Table 2 presents an overview of the clinical purposes of the telemedicine interventions. In 72.5% of the included papers the telemedicine interventions contains two or more technologies of the different categories. Roughly 4 different clinical purposes can be identified:

1. Consultation (27.5%): to enable a in real-time one-to-one or group based contact among patient and healthcare professional during the rehabilitation session;
2. Safety (20%): to enable a safe environment to rehabilitate independently. In these cases during a remote rehabilitation session ECG or saturation level was monitored;
3. Remote supervision and exercising (42.5%): to remotely supervise the patient using sensor-based technology and to actuate the patient to exercise by means of an technology supported exercise-application;
4. Remote supervision and exercising in a stimulating environment (10%): To remotely supervise the patient using sensor-based technology and to actuate the patient to exercise in a stimulating environment.

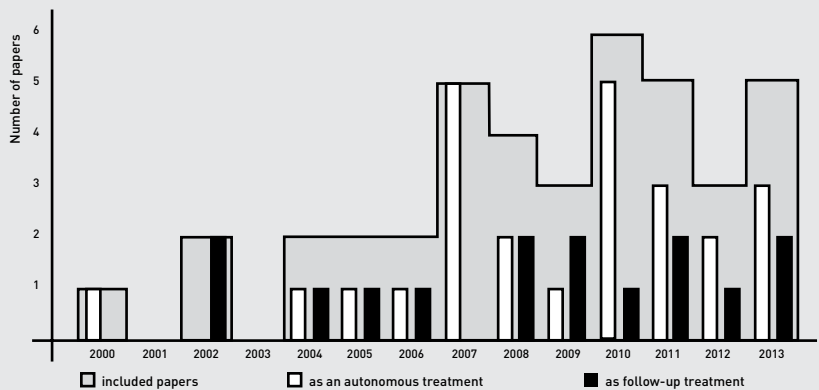
Clinical purpose	Technology used	Number of papers	References
Consultation	synchronous communication	11	[20, 23-25, 27-31, 33, 34]
Safety	synchronous communication + sensor-based	6	[35, 42, 44, 45, 49, 51]
	asynchronous communication + sensor-based	1	[57]
	synchronous + asynchronous communication + sensor-based	1	[46]
Remote supervision and actuate exercising	synchronous communication + exercise-applications	1	[47]
	asynchronous communication + exercise-applications	1	[56]
	synchronous communication + sensor-based + exercise-applications	12	[8, 9, 36-38, 40, 41, 43, 48, 50, 52, 53]
	asynchronous communication + sensor-based + exercise-applications	2	[54, 58]
	synchronous + asynchronous communication + sensor-based + exercise-applications	1	[39]
Remote supervision and actuate exercising in a stimulating environment	synchronous communication + exercise-applications + VR and gaming	1	[32]
	synchronous communication + sensor-based + exercise-applications + VR and gaming	3	[21, 22, 26]

Table 2: Overview of clinical purpose and technology used

Step 2: Service configurations

The service configuration of a telemedicine intervention is hardly mentioned in the majority of the included papers. Figure 2 provides an overview of the service configuration investigated over the recent years. In 15 cases the telemedicine intervention was delivered to the patients as a follow-up treatment [20, 22, 24, 25, 29, 30, 33, 34, 36, 42, 45, 46, 50, 56, 57]: after a period of conventional rehabilitation patients prolonged their rehabilitation at home by means of a telemedicine intervention. For instance, the telemedicine intervention evaluated by Tousignant et al., 2011 [25] facilitated a follow-up treatment for patient who undergone a total knee athroplasty. After discharge from the hospital, patients received two months of physiotherapy at home making use of a videoconference system. In the remaining 22 papers, the telemedicine intervention was

Figure 1: Overview of the number of included papers and the service configuration of the evaluated telemedicine interventions over the years.



Step 3: Added value

Accessibility: All telemedicine interventions have the potential added value to increase the accessibility of healthcare, because technology used allows remote contact among patient and healthcare professional. From a patient point of view increase accessibility means no geographical obstacles or absence of work [43, 44]. Accessibility was not directly parameterized as outcome in the evaluation of the telemedicine intervention. However 25 of the included papers asked of the patient experience in terms of satisfaction and usability. Overall one can state that patients are satisfied with the telemedicine interventions and the interventions evaluated are “easy to use”. Next to the accessibility for the patient, there is also accessibility from the healthcare professional’s point of view what can be defined as the ability to treat more patients simultaneous or to treat patients from a larger geographical area. However whether this is an added value of the telemedicine interventions was not addressed at all.

Quality: Those telemedicine interventions that use technologies to support remote supervision and actuate patients to exercise in their own environment have the potential added value to increase the quality of healthcare as these telemedicine interventions give patients the ability to exercise more often, independently from the availability of a healthcare professional or treatment facilities. In 21 of the included papers technology used gave patient the ability to rehabilitate independently from the availability of a healthcare professional or treatment facilities. Nineteen of these papers assessed clinical outcome. Eleven studies used a prognostic cohort and concluded that telemedicine interventions induced positive changes [38, 39, 41, 43, 45-48, 51, 52, 57]. The other 8 studies were randomized controlled trials. Seven studies found telemedicine intervention at least as effective as conventional care [8, 9, 36, 49, 50, 53, 54] in two of these studies the telemedicine service was delivered to the patient as a follow-up treatment 2 [36, 50]. Only 1 study concluded that telemedicine was more effective as conventional care [40] in this study the telemedicine service was delivered to the patients as a follow-up treatment.

Costs: Especially telemedicine interventions delivered as (partially) replacement of the conventional treatment have the potential added value to reduce costs. From a healthcare professional point of view cost can be reduced when the technology used give

the professional the ability to increase the efficiency of the treatment. Only four of the included papers investigated the costs related to the evaluated telemedicine service. One service was implemented as follow-up treatment [24] and the other three as autonomous treatments [8, 9, 43]). Given the results of these 4 papers can be stated that the efficiency of the treatment can be increased by a decrease in preparation and consultation time [8, 9] or by lowering traveling costs [24]. Besides, telemedicine intervention can also give a reduction of traveling time and costs for patients [8, 43].

Table 3: Main characteristics included papers.

Part1

Paper	Population	Type of intervention	Communication	
			synchronous	asynchronous
			Ades et al., 2000 [44]	Patients with an acute coronary event
Lau et al., 2002 [56]	Patients recovering from shoulder operation	Post-operative care	n.a.	Text, audio or video files
Ueshima et al., 2002 [57]	Patients in the convalescent phase of acute myocardial infarction	Exercise training by using a stepping device	n.a.	Asynchronous messaging device
Lai et al., 2004 [20]	Stroke patient (\leq six months) and able to walk	Community based stroke rehabilitation	Videoconference system	n.a.
Piron et al., 2004 [21]	Stroke patients suffering from mild intermediate arm motor impairments	Motor function rehabilitation	Videoconference system	n.a.
Smart et al., 2005 [46]	Patients with symptomatic heart failure	Exercise program	Telephone	Email
Wong et al., 2005 [23]	Older patients with knee pain	Community based exercise program	Videoconference system	n.a.
Van den Berg et al., 2006 [54] 2007 [55]	Patients with Rheumatoid Arthritis	Intervention to increase physical activity	n.a.	Email
Tousignant et al., 2006 [24]	Geriatric patients	Rehabilitation	Videoconference system	n.a.
Holden et al., 2007 [26]	Stroke patients	Virtual rehabilitation system	Videoconference	n.a.
Page & Levine, 2007 [27]	Stroke patients	Motor function rehabilitation	Videoconference system	n.a.

Technology used				Service configuration
sensor-based technologies	exercise-applications	virtual reality and gaming		
ECG recorder	n.a.	n.a.		autonomous treatment
n.a.	Web application with an individual training program	n.a.		follow-up treatment
Blood pressure monitor and ECG recorder	n.a.	n.a.		follow-up treatment
n.a.	n.a.	n.a.		follow-up treatment
PC workstation equipped with a 3D motion tracking system and generating a virtual reality to exercise				autonomous treatment
Heart-rate monitor	n.a.	n.a.		follow-up treatment
n.a.	n.a.	n.a.		autonomous treatment
Heart-rate monitor	Web application with an (individualize or general) training intervention	n.a.		autonomous treatment
n.a.	n.a.	n.a.		follow-up treatment
PC workstation with motion capture equipment and generating a virtual reality to exercise				autonomous treatment
n.a.	n.a.	n.a.		autonomous treatment

Table 3: Main characteristics included papers.

Part 2

Paper	Population	Type of intervention	Communication	
			synchronous	asynchronous
Pickett et al., 2007 [28]	Stroke patients	Home base constraints induced movement therapy	Videoconference system	n.a.
Zutz et al., 2007 [53]	Eligible patients to attend to cardiac rehabilitation	Cardiac rehabilitation	one-on-one chat	
Burkow et al., 2008 [37]	COPD and diabetes patients	Disease management	Videoconference system	n.a.
Finkelstein et al., 2008 [47]	MS patients	Physical rehabilitation	Telephone	n.a.
Hermens et al., 2008 [36]	Neurological patients: TBI, stroke or MS	Motor function rehabilitation	Videoconference system	n.a.
Piron et al., 2008 [22]	Stroke patients	Virtual post-stroke rehabilitation	Videoconference system	n.a.
Durfee et al., 2009 [52]	Stroke patients	Hand recovery rehabilitation	Telephone / webcam	n.a.
Eriksson et al., 2009 [30] 2011 [29]	Patients who had undergone a shoulder joint replacement	Physiotherapy	Videoconference system	n.a.
Scalvini et al., 2009 [45]	Patient recovering from cardiac surgery	Cardiac rehabilitation	Telephone	n.a.
Brown et al., 2010 [38]	Adults with Cerebral Palsy	Sensor motor training of the upper limb	Videoconference system	n.a.
Huis in 't Veld et al., 2010 [48]; Kosterink et al., 2010 [8]; Sandsjö et al., 2010 [9]	Patients with Chronic pain	Myofeedback treatment	Telephone	n.a.
Kelechi et al., 2010 [31]	Patients with chronic venous disorders	Lower limb physical rehabilitation	Videoconference system	n.a.
Piotrowicz et al., 2010 [50]	Patient suffering from heart failure	Cardiac rehabilitation	Telephone	n.a.

Technology used				Service configuration
	sensor-based technologies	exercise-applications	virtual reality and gaming	
	n.a.	n.a.	n.a.	autonomous treatment
	Blood pressure and heart-rate monitor	Web application with an individual training program	n.a.	autonomous treatment
	Heart-rate, oxygen saturation and blood glucose monitor	Web application with an individual training program	n.a.	autonomous treatment
	n.a.	Web application with an individualized exercise plan	n.a.	autonomous treatment
	PC workstation with tasks and technology to record every training session		n.a.	follow-up treatment
	PC workstation equipped with a 3D motion tracking system and generating a virtual environment to exercise			autonomous treatment
	Computer application with a hand tracking system and a treatment plan		n.a.	follow-up treatment
	n.a.	n.a.	n.a.	follow-up treatment
	ECG recorder	n.a.	n.a.	follow-up treatment
	Computer application with a motion detection system and a treatment plan		n.a.	autonomous treatment
	EMG recorder	Telephone application with continuous feedback on muscle tension / Web application with activity diary	n.a.	autonomous treatment
	n.a.	n.a.	n.a.	autonomous treatment
	ECG recorder	Computer application with an individual training program	n.a.	follow-up treatment

Table 3: Main characteristics included papers.

Part 3

<i>Paper</i>	<i>Population</i>	<i>Type of intervention</i>	<i>Communication</i>	
			<i>synchronous</i>	<i>asynchronous</i>
			Bernocchi et al., 2011 [51]	Patients at risk for cardiovascular events
Bilde et al., 2011 [39]	Children with cerebral palsy	Rehabilitation with	Videoconference system	Email
Kowalczewski et al., 2011 [32]	Patients with spinal cord injury (tetraplegic)	Functional electrical stimulation (FES)	Videoconference system	n.a.
Tousignant et al., 2011 [25]	Patient who undergone total knee arthroplasty	Physiotherapy	Videoconference system	n.a.
Deng et al., 2012 [40]	Stroke patients	Ankle movement training	Videoconference system	n.a.
Marios et al., 2012 [49]	Patients with type II diabetes	Individualized walking program	Telephone	n.a.
Corriveau et al., 2012 [33] [34]	Stroke patients	Balance exercise program	Videoconference system	n.a.
Holland et al., 2013 [35]	COPD patients	Exercise program by using a cycle ergometer	Videoconference system	n.a.
Langan et al., 2013 [41]	Stroke patients	Sensor motor training of the upper limb	Videoconference system	n.a.
Scalvini et al., 2013 [42]	Patient recovering from cardiac surgery	Cardiac rehabilitation	Videoconference system	n.a.
Zanaboni et al., 2013 [43]	COPD patients	Exercise program by using a treadmill	Videoconference system	n.a.

Technology used			Service configuration
sensor-based technologies	exercise-applications	virtual reality and gaming	
ECG recorder	n.a.	n.a.	autonomous treatment
Web application with a motion detection system and a treatment plan.		n.a.	autonomous treatment
n.a.	PC workstation with Functional electrical stimulation (FES) garment to stimulate hand opening and grasping and custom computer games		autonomous treatment
n.a.	n.a.	n.a.	follow-up treatment
PC Workstation with an ankle motion tracking device and a treatment plan.		n.a.	autonomous treatment
Heart-rate monitor	n.a.	n.a.	autonomous treatment
n.a.	n.a.	n.a.	follow-up treatment
Pulse oximeter	n.a.	n.a.	autonomous treatment
Computer application with a motion detection system and a treatment plan.		n.a.	autonomous treatment
ECG recorder	n.a.	n.a.	follow-up treatment
Pulse oximeter	Web application with an individual training program	n.a.	autonomous treatment

Discussion

The aim of this paper was to present an overview of the current state of the technology used, the clinical purpose and service configuration of telemedicine interventions facilitating remote physical rehabilitation. Subsequently it was assessed whether the potential added value of the telemedicine services is correctly shown. Concerning telemedicine intervention facilitating remote physical rehabilitation the technology used and the clinical purpose were various. In most cases the clinical purpose of the telemedicine intervention was remote supervision and exercising. The majority of the telemedicine interventions were evaluated as autonomous treatment and the remaining telemedicine interventions were evaluated as follow up treatment. Concerning the added value, the outcomes of the evaluations of the included papers are not related to the hypothesized added value on beforehand and focus largely on clinical outcome, only. In addition, the literature reviews that addressed the potential of telemedicine intervention for physical rehabilitation so far [14-16, 18, 19, 58] did not categorize the telemedicine interventions at all and tried to identify the true potential for the various telemedicine interventions as once. However, as technology used, clinical purpose and service configurations together identify the added value and as such expected potential of the intervention under investigation it is to our opinion strange that these are never considered in relation to the study design, study population and outcome on beforehand. Based on this it can be concluded that the true potential of telemedicine interventions is far from known.

Future steps

Taking the technology and service configuration into account directly poses a challenge to the evaluation methodology. It raises the question whether currently used research designs could be applied to gain conclusive evidence for these telemedicine interventions [2, 3, 18] because of a number of aspects. Firstly, a pragmatic reason is the fact that suggested service configuration has (in most cases) big organizational impact on the healthcare process. Implementation of a telemedicine intervention into conventional healthcare changes the availability of healthcare professionals and treatment rooms. In these cases, a randomized controlled trial is pragmatically not feasible and to gain conclusive evidence, the use of a historic or prognostic cohort as control group to evaluate the telemedicine intervention, can be in this situation a valuable option.

Secondly, patients have preferences concerning the use of telemedicine in their rehabilitation treatment [59]. It serves no purpose to use telemedicine intervention in the treatment of a patient with no interest in ICT and with a lack of computer skills. Telemedicine interventions have the advantage to personalize the physical rehabilitation and to take into account these preferences. Therefore, the deployment of telemedicine intervention (i.e. technology used) can be different for the various patients and clinical trials do not allow for such variability.

Finally, currently technology innovates very quickly whereas randomized controlled trials take time. With the consequence, that during the trial the technology used (cq. telemedicine intervention) becomes outdated. Patient could be less motivated to comply with the outdated telemedicine intervention. Low compliance to a telemedicine intervention could have a negative influence on the effectiveness of the intervention

[36, 48]. To overcome these three aspects less conservative research designs, such as single-case design and factorial design, should be used to gain conclusive evidence and evaluate the potential of telemedicine interventions.

In conclusion, this paper is a first attempt to obtain insight in telemedicine services facilitating remote physical rehabilitation by concerning the heterogeneity in the technology used, clinical purpose and as well as the service configuration. However, the technologies used and clinical purpose are diverse and the service configuration where telemedicine is used as partly replacement of traditionally care is not addressed. As such, the true potential of telemedicine interventions is far from known. It is expected that this seriously hampers implementation of telemedicine interventions into every day healthcare practices. Future studies should focus on evaluation telemedicine interventions in the way they need to be implemented in every day care to contribute to the challenges of rising demand for and costs of health care.

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CHAPTER 5

Relation between patient satisfaction, compliance and the clinical





benefit of a teletreatment application for chronic pain

Huis in 't Veld MHA, Kosterink SM, Barbe T,
Lindegard A, Marecek T & Vollenbroek-Hutten
MMR. Journal of Telemedicine and Telecare
2010; 16: 322–328

Summary

Objective: The aim of the current study was to investigate the ease of use and usefulness as a measure of patient satisfaction, compliance, clinical benefit and its mutual relationships concerning a tele-treatment application for chronic pain.

Methods: In total, fifty-two subjects with neck-shoulder pain received and completed a four week myofeedback based teletreatment (MyoTel) intervention. Prior to the onset of the intervention (at baseline) and immediately after the intervention (T0) they were asked to fill in questionnaires to measure discrepancies (gap scores) between expectations and experiences with the ease of use and usefulness of the Myotel treatment as well as pain intensity and pain disability. In addition, the actual use of the system (i.e. the amount of muscle activity data available on the server) was logged. T-tests were applied to investigate differences in expectations and experiences and clinical outcomes between B and T0. Correlations coefficients were used to investigate the mutual relationships between compliance, satisfaction and clinical benefit.

Results: subjects reported a significant higher score on ease of use after the intervention (T0) compared to baseline (B) suggesting that the Myotel technology was easier to use than they expected. Moreover, compliance to the intervention tended to be associated with (clinical) benefit, pain disability in particular. No significant relations could be found between patient satisfaction and compliance.

Conclusion: it is considered to be important to measure patient satisfaction as a key indicator to how well the telemedicine treatment has met expectations and to monitor compliance because of its association to clinical outcomes.

Introduction

In telemedicine, methodologies and tools for assessing satisfaction are not clearly specified in many studies, making interpretation and comparison of results problematic.[5] Theoretical constructs are recommended to form the underlying framework for measuring satisfaction. The theory of reasoned action (TRA), is one of the most influential theories of human behaviour.[6] The TRA states that the proximal determinant of behaviour is the intention to perform or to not perform that behaviour. In other words, the stronger the intention to use a technology, the more that user is going to accept the technology. Davis et al. [8] applied TRA to individual acceptance of technology to information system contexts and 'designed' the so-called Technology Acceptance Model (TAM) to predict and explain usage of technology and found that the variance explained was largely consistent with studies that had employed TRA in the context of other behaviours. According to the Technology Acceptance Model[8], the proposed factors that shape the intention to accept a technology are 'ease of use' and 'perceived usefulness'.

In general, the more positive one's perceived usefulness and ease of use with respect to the telemedicine intervention, the more likely one is to form a strong intention and to actual use and clinically benefit from it. Surprisingly, there is hardly any research linking user satisfaction with actual usage of (telemedicine) systems[9] and the relation between actual usage and clinical benefit. In conventional health care, dissatisfied patients may miss appointments, fail to comply with prescriptions thereby risking adverse clinical outcomes.[10] In conventional health care settings treatment satisfaction[11] and compliance[12] have a positive effect on clinical outcomes. Dissatisfied patients could influence the use, i.e. an indicator for treatment compliance, of telemedicine technologies and thus clinical benefit of the intervention. Understanding these relationships could be used to target compliance-enhanced adaptations of the telemedicine intervention in future design.

Mair and Whitten (2000)[5] performed a systematic review of studies concerning patient satisfaction with teleconsultation services. Their results showed that studies commonly evaluate patient satisfaction after usage (of a prototype) of the telemedicine service. However, theories among which is the SERVQUAL concept[13], include patient expectations as the basic concept of satisfaction.[14,15] A common definition of satisfaction is therefore the degree of congruence between expectation and accomplishment.[16,17] Logically, we have to know what patients expect before we ask them about their satisfaction with the care they received.

The subjective experienced quality of service delivery is defined as the gap'between the expectations and actual experience of customers.[13] Examining discrepancies in patients' perceptions of and experiences with the service reveals whether the expectations of users were 'fulfilled' or whether they were 'disappointed' by the care they received. This is especially relevant in the field of telemedicine services, because of their innovative character. Innovation is, by definition, about technologies, services and products that differ from what is known from today's experience. Normally expectations are shaped by its own specific experience and knowledge, but in innovations these aspects are not present. In telemedicine, patients are confronted with high uncertainties regarding technological characteristics and future use since they commonly do not have (yet) prior expe-

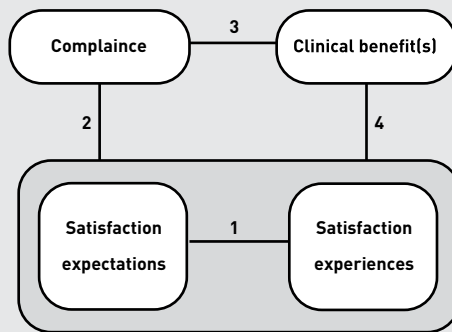
rience. Consequently, expectations could be unrealistic thereby influencing satisfaction after actual usage. In case of disappointment, baseline expectations are higher than the actual experience. When disappointed, the acceptance by end-users is likely to be at risk and adaptations in the next design cycle could be considered.

We have examined satisfaction of end-users with tele-treatment.

The aims of the study (Figure 1) were to:

- (1) investigate the discrepancy between expectations and experiences with the ease of use and usefulness of the tele-treatment service as a measure for satisfaction;
- (2) investigate the relation between satisfaction and compliance with the tele-treatment service;
- (3) investigate the relation between compliance of the tele-treatment service and the clinical benefits on perceived pain intensity and pain disability;
- (4) investigate the relation between the clinical benefits and satisfaction of the tele-treatment service.

Figure 1 Research framework of current study.



This illustrates the relation between the different 'constructs' (e.g. compliance, clinical benefits and satisfaction) to be investigated which are hypothesized to be inter-related. The numbers refer to the research questions listed in the paper. The boxes are linked in a circular fashion because we hypothesize these theoretical constructs presented in the three boxes to be inter-related. Since the relation between these constructs has hardly been investigated before, we hypothesize bi-directional relationships between them. For example, people who are more satisfied with the treatment are hypothesized to be more compliant. But the opposite direction could be valid as well, i.e. people who are very compliant to the treatment are probably more satisfied. In addition, people who have experienced large clinical benefits from the treatment, probably have had a higher treatment intensity (i.e. they are more compliant). Furthermore, as described in the Introduction, the level of perceived satisfaction with the treatment could influence the clinical benefits that people perceive. People who have noticed large clinical benefits because of the treatment will probably be more satisfied about the treatment they received compared to people who did not notice hardly any clinical benefit. The two satisfaction boxes are inside another box because we hypothesize (in line with the SERVQUAL concept) that the discrepancy between expectations and experiences is a measure for satisfaction

Methods

The research focused on a myofeedback based tele-treatment for subjects with complaints in the neck-shoulder region. The tele-treatment consists of a garment which patients wear underneath their clothes during normal life. The garment continuously registers the lack of muscle relaxation. In case of insufficient amounts of muscle relaxation, the system starts vibrating as a sign to relax. The recorded data are sent to a website which can be accessed by the therapist. The data are discussed with the patient during weekly teleconsultations. Subjects wear the system for four weeks during their daily activities and continuously receive feedback when their muscle relaxation is insufficient. The monitoring and feedback during everyday activities enables rapid adaptation of the subject's behaviour and tends to show long lasting effects of treatment [18,19,20].

Participants

Two groups of users were studied; patients with non-specific neck-shoulder pain (e.g. whiplash associated disorder) and subjects with neck-shoulder complaints related to computer work. Subjects were recruited by centres in four different countries: The Netherlands, Sweden, Germany and Belgium. The centres in Germany, and Belgium treated patients diagnosed with a WAD (whiplash associated disorder) while the centre in Sweden treated patients with work-related (WR) neck-shoulder symptoms. The centre in the Netherlands treated patients with both disorders. The study was approved by the appropriate ethics committees of the different countries and all participants gave informed consent.

Subjects were screened by means of a questionnaire that asked about neck-shoulder pain.[21,22] Subjects were included if they were of working age, female gender, experienced complaints in the neck or shoulder region for more than 7 days during the previous month. In addition, only subjects with average pain intensity of >3 cm on a 10 cm VAS-scale during the previous month were included. Exclusion criteria were use of muscle relaxants, diagnosed (general) pain syndromes (e.g. fibromyalgia, arthrosis), excessive overweight (Body Mass Index >30 kg/m²), involvement of subjects in any legal procedure or insufficient understanding of the language spoken during the intervention. The following inclusion criteria were specific for subjects with work-related neck-shoulder pain (see Table 1).

Work related	Non-specific neck and shoulder pain	
Working at least 20 hours a week	Diagnosis of whiplash disorder provided by a health professional	<i>Table 1. Specific inclusion criteria for subjects with work-related neck-shoulder pain and patients with non-specific neck-shoulder pain (whiplash)</i>
Performing computer work predominantly		
Similar work task for at least 12 months	Performing working and/or sick leave	
Pain due to computer work (own impression)		
Duration of complaints >3 months		

Measurements - satisfaction

User satisfaction was measured by means of an adapted version of the questionnaire proposed by Hu et al.[24] The Technology Acceptance Model (TAM)[8] was used as the underlying theoretical framework to construct the questionnaire. This model suggests that the behavioural intention toward usage of technology is indirectly preceded by perceived usefulness and perceived ease of use. Therefore, items of the questionnaire were directed at assessing the patient view about perceived usefulness, perceived ease of use, and their intention for future MyoTel treatment use/adherence. The ease of use scale as well as the usefulness scale comprised four items (Appendix 1). Expectations of subjects about the MyoTel service were assessed prior to treatment, at baseline, and experiences were assessed immediately after the four week MyoTel period (T0).

Measurements – compliance/use of system

The number of minutes the system was worn by the patient, i.e. the interval between log-in and log-out time, was registered by the system automatically each day. In order for the myofeedback therapist to conduct a meaningful teleconsultation, a minimum of eight hours of muscle activity data was required per patient per week, preferable divided over 2-3 days[20].

Measurements – clinical benefits

Pain intensity

Pain intensity was assessed on a visual analogue scale (VAS) [25,26]. Subjects were asked to rate their experienced level of pain “during the past month” on a 10 cm horizontal line with “no pain at all” at the left and “as much pain as possible” at the right extremity of the line.

Pain disability index

The level of subjectively experienced disability was assessed with the Pain Disability Index (PDI), a self-rating scale that measures the impact of pain on ability to participate in life and activities. The PDI contains 7-items one for each domain, i.e. (1) family and home responsibilities, (2) recreation (sports and leisure time activities), (3) social activity (participation with friends and other acquaintances), (4) occupation (activities partly or directly related to working), (5) sexual behaviour (frequency and quality of sex life), (6) self-care (basic life-supporting behaviours) and (7) daily activities. Answers were provided on a categorical 11-point scale with “not disabled” (score 0) and “fully disabled” (score 11) as verbal anchors. In a chronic pain population, the psychometric properties of the Pain Disability Index appeared to be sufficient[28].

Data analysis

To investigate the quality of the satisfaction questionnaire the reliability coefficients (cronbach's alpha) were calculated for the two subscales, i.e. ease of use and perceived usefulness. An alpha coefficient >0.70 is considered to be reliable [29]. Thereafter, the scores on the negative phrased/formulated items were re-coded to positive formulated item scores and the sum scores on the satisfaction questionnaire were calculated for both subscales on baseline and immediately after the four week intervention period. Paired t-tests were applied to examine the significant differences between baseline and T0 (im-

mediately after the intervention) scores on the satisfaction scales, pain intensity and pain disability scores.

To investigate the usage of the MyoTel service the average amount of hours of data available per patient per day and per treatment week (4 treatment weeks in total) was calculated as well as the number of days data was available per week.

To investigate the relation between satisfaction at T0 and usage of the system, the compliance i.e. the sum of number of hours available in four weeks was calculated. In addition, to investigate the relation between compliance and clinical benefits, changes in pain intensity and disability were calculated: VAS and PDI scores obtained at T0 were subtracted from B values and expressed as difference (gap) scores, i.e. Δ VAS B-To and Δ PDI B-To. Change scores provide information on the magnitude of the clinical benefit and are therefore, in our opinion, represent a more relevant measure to correlate with usage and satisfaction compared to absolute values of pain intensity at To. As the level of change depends on the baseline score, inclusion of baseline values are preferred. Both the direction and the size of the change score, e.g. the gap, are relevant to investigate the satisfaction of patients with the tele-treatment service. For the gaps calculated for the subscales of the satisfaction questionnaire, Δ Ease of use To-B and Δ Usefulness To-B, the baseline scores were subtracted from the T0 scores to make the interpretation of the satisfaction Δ scores similar to the interpretation of clinical Δ scores. More concrete, a positive Δ score indicates satisfaction with the MyoTel service and clinical benefits on pain and disability and a negative Δ score suggests disappointment and deterioration in health status. The larger the Δ scores the larger the effects on satisfaction and clinical benefits.

It was hypothesized that a larger (positive) change in clinical benefit and satisfaction is associated with higher compliance. Pearson's correlations between compliance (number of hours of muscle activity data), the ease of use and usefulness subscales of the satisfaction measure, Δ Ease of use To-B and Δ Usefulness To-B, Δ VAS B-To and Δ PDI B-To were examined. A standard package (SPSS) was used for statistical analysis.

Results

In total, 82 subjects were included for the MyoTel intervention. In the time period between screening and six-month follow-up, 30 patients (37%) dropped out because of technical problems with the equipment or personal circumstances, such as lack of time or motivation. Thus, 52 patients (63%) finished the four week intervention. In this group, 22 subjects suffered from computer work-related complaints and 30 subjects suffered from non-specific neck-shoulder pain, mainly diagnosed as whiplash associated disorder. At the time of inclusion, the average age of the subjects was 39.7 years (SD 10.8), the average height was 167.0 cm (SD 6.8), and weight was 67.25 kg (SD 10.65). The average number of days that they reported symptoms in the neck-shoulder area was 20.8 (SD 10.6).

Satisfaction and clinical changes

The scores for the expected (B) and perceived (T0) ease of use and usefulness subscales of the satisfaction, pain intensity and pain disability data are summarised in Table 2. With respect to the reliability analysis of the satisfaction scales, the alpha coefficient of the four item 'ease of use' scale was 0.7, indicating a moderate reliability. The alpha coefficient of

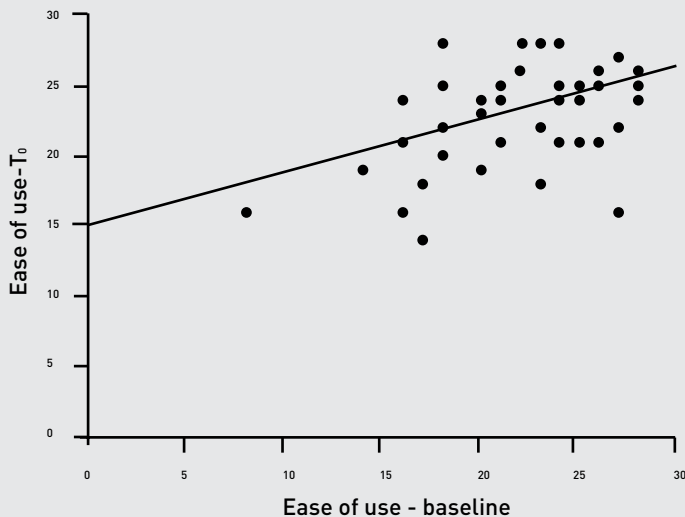
Table 2. Satisfaction (usefulness, ease of use), pain intensity (VAS) and pain disability (PDI)

	No.	Range of scores	Baseline mean Scores (SD)	After Treatment mean Scores (SD)	P value
Usefulness (4 items)	45	4-28	20.6 (4.1)	20.3 (5.1)	0.73
Ease of use (4 items)	45	4-28	21.7 (4.3)	23.3 (3.9)	0.024
Pain intensity neck and shoulder during previous month	52	0-10	5.7 (1.9)	4.7 (2.2)	< 0.001
Pain Disability Index	52	0-70	22.5 (15.1)	17.3 (13.8)	0.002

0.8 of the four item 'perceived usefulness' scale indicated a good reliability. A significant reduction in pain intensity ($P < 0.001$) and pain disability ($P = 0.002$) was found after four weeks of MyoTel treatment. After having received four weeks of MyoTel treatment (To) subjects reported a significant higher ($P = 0.024$) perceived ease of use of the system compared to the expected ease of use prior to the start of the MyoTel treatment (B). The anticipated usefulness (B) was equal to the perceived usefulness at To ($P = 0.73$). It could be hypothesized that patients who had higher expectations about the usefulness and ease of use of the MyoTel intervention dropped out because they became disappointed after receiving the intervention. However, additional analysis showed no significant differences in baseline values of the variables included in Table 2 (pain intensity, pain disability, ease of use and usefulness) among subjects who completed the four-week MyoTel intervention compared to the drop-outs ($P > 0.25$).

Illustrated by the scatterplot presented in Figure 2, a significant correlation ($r = 0.42$, $P = 0.004$) was found between the expectations and experiences about the ease of use of the MyoTel intervention. It can be concluded that on average higher expectations about ease of use also resulted in higher scores on actually perceived ease of use. No such association between expectations and experiences was found for the usefulness subscale

Figure 2. Relationship between expectations (B) and experiences (T0) about ease of use



of the satisfaction questionnaire ($r=0.22$, $P=0.151$) (Figure 3).

On an individual level, the majority of the subjects ($n=31$) reported a positive gap between T0 and B regarding the ease of use of the MyoTel equipment, indicating satisfaction, whereas $n=14$ subjects reported dissatisfaction (negative gap). Likewise, a positive gap was found in the majority of subjects ($n=26$) suggesting that they perceived the MyoTel intervention to be more useful compared to what they expected from it prior to the start. Nineteen subjects perceived the MyoTel intervention to be less useful after usage.

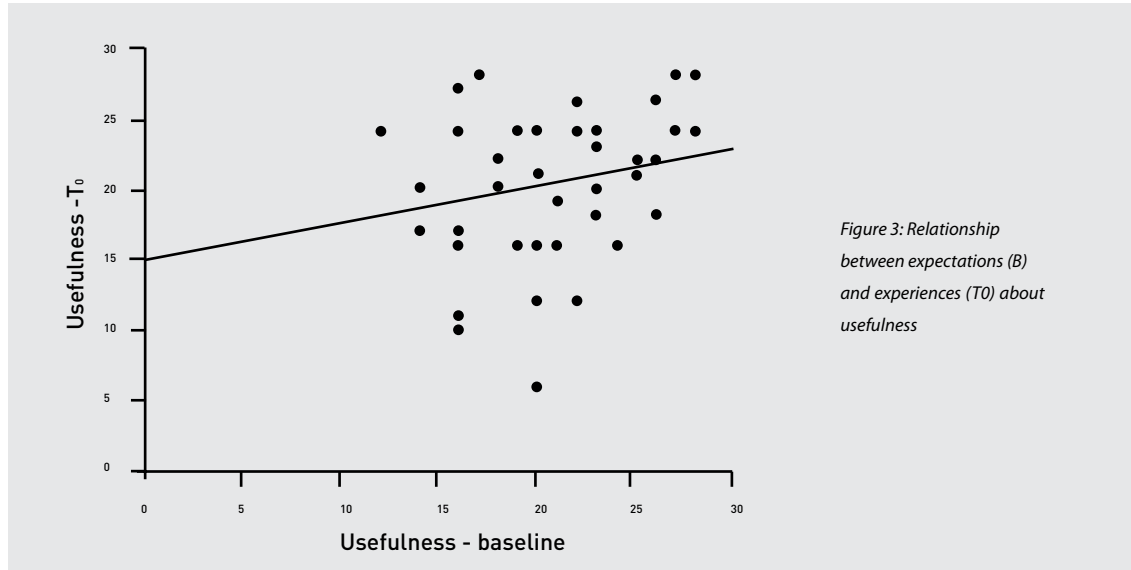


Figure 3: Relationship between expectations (B) and experiences (T0) about usefulness

Compliance with tele-treatment

As presented in Table 3, the average time during which the MyoTel system was worn ranged from 14.3 hours per week (week 1) to 9.5 hours per week (week 4). The average duration remained higher than the 8 hour threshold defined by the therapists. Subjects used the system for 2.8 days per week (week 4) to 4.5 days per week (week 1) approaching the recommendation of the therapist to wear the system 2 to 3 days per week. The average time during which the MyoTel equipment was used declined over time and so did the number of days per week in which the equipment was used. In contrast, the number of hours per day using the MyoTel equipment increased slightly over time. However, there was a large variability.

	Week 1 (N=52)	Week 3 (N=52)	Week 3 (N=52)	Week 4 (N=52)
Number of hours	14.3 (8.7)	12.6 (8.0)	11.1 (7.3)	9.5 (7.0)
Number of days	4.5 (1.5)	3.6 (1.4)	3.3 (1.5)	2.8 (1.6)
Hours per day	3.1 (1.2)	3.3 (1.4)	3.3 (1.3)	3.4 (1.6)

Table 3. Compliance with the treatment. Values shown are means (SDs)

Correlation satisfaction, compliance and clinical benefits

The relationships among satisfaction, compliance with the MyoTel treatment and the clinical changes during the four week intervention period are summarised in Table 4. There were no significant correlations between satisfaction, compliance and clinical benefits. There was a trend between compliance with the MyoTel treatment and the changes (Δ score) in disability score ($r=0.25$, $P=0.073$). This suggests that the more compliant subjects are to the MyoTel intervention the more they benefited from it (on a disability level).

Table 4. Correlation between satisfaction, compliance and clinical benefit (n=45)

			Compliance	Clinical benefit	
			Total hours	Δ VAS B-To	Δ PDI B-To
Satisfaction	Ease of use	B	-0.168 p=0.260	-0.021 p=0.887	0.078 p=0.604
	Usefulness	B	0.000 p=0.999	-0.057 p=0.701	-0.199 p=0.175
	Ease of use	To	0.088 p=0.554	-0.048 p=0.745	0.114 p=0.441
	Usefulness	To	0.167 p=0.257	0.048 p=0.745	-0.066 p=0.656
	Δ Ease of use To-B		0.179 p=0.238	-0.024 p=0.877	-0.014 p=0.926
	Δ Usefulness To-B		0.140 p=0.355	-0.054 p=0.724	0.072 p=0.635

One could hypothesize more salient associations in subjects who were 'satisfied' (e.g. showed a positive gap on the ease of use subscale, n=31) of the MyoTel intervention. Compared to the results presented in Table 4, a similar pattern of results was found except for a significant correlation was found between compliance, i.e. the number of hours, and Δ VAS B-To ($r=$ indicating the more compliant the higher the clinical benefit on pain intensity). However, there was no significant differences in compliance, Δ VAS B-To, or Δ PDI B-To compared to subjects who were not classified as 'satisfied' ($P>0.115$).

Discussion

The present study investigated the relation between discrepancies in ease of use and usefulness as a measure for patient satisfaction, compliance, clinical benefit and its mutual relationships concerning a myofeedback based tele-treatment (MyoTel) application for subjects suffering from neck-shoulder pain. Four research questions were addressed (Figure 1).

There was a significant discrepancy between expectations (B) and actual experienced (T0) ease of use of the MyoTel equipment. In general, the majority of subjects found the MyoTel equipment easier to use than they expected prior to the start of the intervention, suggesting that they were (at least) not disappointed. At a group level no significant discrepancy between baseline and end of MyoTel intervention was found for the usefulness

subscale suggesting that subjects had a realistic view about its usefulness prior to the intervention. However, the results of the analysis on an individual level were more conclusive. The majority of the subjects reported a positive gap, indicating fulfillment with the anticipated usefulness of the MyoTel intervention.

There was no relation between satisfaction and compliance with the MyoTel intervention. Although numerous empirical studies have found that the Technology Acceptance Model (TAM) consistently explains a substantial proportion of the variance (typically about 40%) in usage intentions and behavior [30], a possible explanation could be that actual use of the MyoTel technology is more determined by other factors than the ones postulated in the TAM model, i.e. ease of use and usefulness. For instance, according to the Unified Theory of User Acceptance of Technology (UTAUT) factors like gender, voluntariness of use, facilitating conditions and social influence also determine the usage of a technology. [31] Another explanation could be the operationalization of 'amount of muscular activity data available on the server' for 'compliance' as applied in the present study. The amount of muscular activity data available could have been affected by 'usage inconvenience' barriers, e.g. system failures or power restrictions that were not related to the constructs of 'ease of use' and 'usefulness' included in the satisfaction questionnaire applied. Retrospective qualitative analysis, i.e. interviews and/or focus groups, could be applied to try to discover the exact barriers for the decline in compliance in the course of the MyoTel treatment. The knowledge of the different aspects that leads a patient to comply with tele-treatment interventions and the reasons given by the patients to justify non-compliance, may help to improve therapeutic adherence in future.

Data concerning the usage of the system revealed interesting information about the compliance of patients with the MyoTel intervention. The results indicated that patients showed a small decline in the average weekly usage of the system during the four-week intervention period. An explanation could be that patients experienced the clinical benefits of the treatment early during the intervention and managed to apply an appropriate way of using their painful muscle, resulting in less need of the system in order to cope with pain. The decline was especially evident in the average amount of days the system was worn whereas the average amount of hours the system was worn per day remained the same. So, a second possible explanation is that in the course of the treatment period patients got tired of turning the system on and off. According to the theory of reasoned action (TRA)[6], which formed the basis for the Technology Acceptance Model, subjects rationally choose (non-) compliance when the barriers (i.e. efforts, costs) outweigh the expected benefits.[8] The fact that the number of days the system was worn declined and the duration the system was worn per day remained stable could mean that the barrier (perceived 'effort') no longer outweighed the (clinical) benefits they experienced. In other words, patients became 'tired' of putting on and off the system every day.

With respect to the third research questions, a trend was found between compliance of the system and clinical benefit. Higher usage of the system appeared to be significantly associated with a beneficial change in self-reported disabilities. The MyoTel intervention allowed subjects to be treated more frequently, i.e. a high number of hours on a daily basis. In addition, the vibration and availability of muscle activity data on the visual display of the PDA provided them with continuous and high-detailed information about the

success of their relaxation skills applied. It is known that a higher intensity of treatment [32] and more detailed feedback on performance during training [33] are associated with larger functional benefits.

With respect to the fourth research question, no direct relation was found between the clinical benefits and satisfaction. Although little is known about the relation between satisfaction and clinical outcomes in telemedicine literature, this finding contradicts some of the findings of other studies conducted among pain patients. In a study of Hurwitz and Morgenstern [34], the self-reported clinical improvement was greater among pain patients who were highly satisfied about the back care programme they had received. In a neck pain population, clinical improvement after surgery was found to be associated with improved patient satisfaction.[35]

The present study was limited by the relatively small sample (n=45) size and reliance on the satisfaction questionnaire applied. Despite the fact that a theoretical underpinning was used and a sufficient internal consistency was found, the questionnaire might have been too generic to evaluate all aspects related to the satisfaction with the Myotel system. The lack of a validated and reliable satisfaction instrument has frequently been recognized to be a problem [5,23].

In conclusion, it is important to measure patient satisfaction as a key indicator to how well the telemedicine treatment has met expectations and to monitor compliance because of its association to clinical outcomes as found in the current study. Given these findings, we advocate the use of difference (gap) scores, since they provide a superior indicator of satisfaction by gauging the magnitude of difference between a user's expectations and perceptions. According to the SERVQUAL concept, having insight in the factors showing discrepancies in customer's expectations and experiences could help shape up the effort for a service provider to bridge the gap and, thereby, to enhance the quality of service for the customer[13]. For instance, a disappointment gap concerning the ease of use of a telemedicine application could be bridged by adapting the technology in the next (re-) design phase of the prototype or the incorporation of more elaborated instruction material/ sessions for patients on how to use the equipment. A disappointment gap concerning the usefulness could be bridged by providing patients with more relevant or accurate information about the treatment prior to the start. The importance of implications of the associations between satisfaction, compliance and clinical outcomes remains to be clarified by further study but, in our view, better understanding is required to improve the quality of telemedicine service delivery, e.g. by means improving design and user training, and its adoption by patients.

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Appendix 1 Satisfaction questionnaire

Answering format:

I strongly disagree

I strongly agree

1	2	3	4	5	6	7
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Questionnaire at Baseline (B): expectations

Easy of use (B)

1. Dealing with the Myotel technology will not be easy for me.
2. I expect it will be easy to let the Myotel technology do what it should do for me in treating my neck-shoulder pain.
3. It will not be easy for me to be skilled in using the Myotel technology.
4. I will find the Myotel technology easy to use.

Usefulness (B)

1. The use of the MyoTel technology will not lead to an improvement in my neck-shoulder pain.
2. The use of the MyoTel technology will make treatment easier.
3. The use of the MyoTel technology will not enhance the effectiveness of my treatment.
4. I will find the use of the MyoTel technology not useful for my neck-shoulder pain.

Questionnaire after intervention (T0): experiences

Ease of use (T0)

1. Learning to operate the MyoTel technology was not easy for me.
2. I found it easy to let the MyoTel technology do what it should do for me in treating my neck-shoulder pain.
3. It was not easy for me to be skilled in using the MyoTel technology.
4. I found the MyoTel technology easy to use.

Usefulness (T0)

1. The use of the MyoTel technology did not lead to an improvement in my neck-shoulder pain.
2. The use of the MyoTel technology made treatment easier.
3. The use of the MyoTel technology have not enhanced the effectiveness of my treatment.
4. I found the use of the MyoTel technology not useful for my neck-shoulder pain.



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CHAPTER 6

A telemedicine service as a partial replacement of face to face physical rehabilitation. The relevance of use.

Abstract

Background: Different kinds of telemedicine services have made their entry into healthcare. In this paper we focus on an exercise-based telerehabilitation service, designed and implemented as partial replacement of a 3 days outpatient rehabilitation program for chronic patients.

Introduction: To give recommendation to optimize this kind of services the aim of this paper is to examine the use pattern of an exercise-based telerehabilitation service by chronic patients and to examine the association between actual of use and clinical benefit experienced by the chronic patients.

Materials and Methods: Chronic low back pain patients and pulmonary disease patients referred to the physical outpatient rehabilitation programs were asked to participate and to use the exercise-based telerehabilitation service. The actual use is expressed as frequency and duration of use and measurement on clinical benefit focuses on complaints and physical functioning.

Results: 62 patients finished the outpatient rehabilitation using the exercise-based telerehabilitation service. During the weeks of home rehabilitation 52-90% of the patients used the service. On average the service was used 1-2 times a week for in total 35-38 minutes for both pathologies which is lower than the time that is replaced. Frequency of use is significantly related to the change in physical functioning score for both pathologies (CLBP: $r=0.41$, $p=0.02$ and PD: $r=0.55$, $p=0.003$).

Conclusion: Chronic patients use a telerehabilitation service as partial replacement of their face-to-face RP and more frequent use is positively related to higher clinical benefit. Therefore the actual use of a telemedicine service should be taken into account when studying its outcome.

Introduction

The concept of healthcare continues to change. Due to the economic imperative to restrain rising healthcare costs, in the context of an ageing community and the extraordinary changes in communication technology, different kinds of telemedicine services have made their entry into healthcare [1]. There is not one definitive definition of telemedicine [2] but following the World Health Organization (WHO) Telemedicine services are healthcare services where information and communication technologies (ICT) is used by healthcare professionals to exchange information for the treatment of a patient [3]. Next to the potential to lower healthcare costs telemedicine services have the potential to increase the accessibility and quality of care [4,5].

Especially telemedicine services that enable asynchronous remote supervision by a healthcare professional and actuate patients to perform exercise in their own environment have the potential to increase the quality of care. These kinds of exercise-based telerehabilitation services [6-8] give patients the opportunity to increase the intensity of their rehabilitation, as they can rehabilitate independently from the availability of healthcare professionals and treatment rooms. This fits in the current trend of patient-centered care [9]. In literature there is insufficient evidence regarding the effectiveness of such exercise-based telerehabilitation services partly attributed to the low methodological quality of clinical studies [1, 10-12]. Besides, most of these evaluations can be considered as black box evaluation. Black box evaluation may provide an assessment of whether or not a telemedicine service is effective but fail to identify the underlying mechanisms that generate its effects [13]. Knowledge about the actual use of the telemedicine service could be a first step to unravel this black box.

Concerning physical rehabilitation there is some evidence that intensive programs are more effective than programs with a lower level of intensity [14]. For telemedicine service in rehabilitation this association between use and clinical benefit has been the topic of some papers. According to Hermens et al., 2008 [15] chronic stroke patients with high training intensity had a better change on the improvement of arm/hand functions using an exercise-based telerehabilitation service. Huis in 't Veld et al., 2010 [16] showed that chronic pain patients who used a telerehabilitation service more often (i.e. expressed in the number of hours) had higher clinical benefit in pain relief. These findings are verified by Rho et al., 2014. Their paper showed that high compliance has a positive impact on the clinical outcome [17] However, in these papers the telemedicine service was delivered to the patients (service configuration) as an autonomous treatment [16,17] or as follow up treatment [15]. In none of the papers the telemedicine service was delivered to the patients as a partial replacement of face to face physical rehabilitation. To the author's best knowledge, there are no studies so far that studied the use of telemedicine service when delivered as a partial replacement of face to face physical rehabilitation and as such it is unknown whether in this case higher use is also related to better clinical outcome.

In this paper we focus on an exercise-based telerehabilitation service, designed and implemented as partial replacement of a 3 days outpatient group multidisciplinary rehabilitation program (RP) for patients with chronic low back pain (CLBP) or pulmonary disease (PD). An earlier paper showed that this service is as effective as the conventional outpatient RP [18]. To unravel the black box concerning the effectiveness of the exercise-based telerehabilitation service and to give recommendation to optimize this kind of

telemedicine services the aim of this paper is to examine the use pattern of an exercise-based telerehabilitation service by chronic patients and to examine the association between actual of use and clinical benefit experienced by the chronic patients.

Methods

This paper focused on an exercise-based telerehabilitation service for two chronic pathologies. To gain insight in the generality of the actual use and association between actual of use and clinical benefit experienced by the chronic patients, two pathologies groups are included. This service consists of a notebook with webcam and two treatment modules. The first module contains a database of exercise videos. The second module, a teleconference service, facilitates contact between patient and physiotherapist. During the first 2 weeks (for CLPB) or 4 weeks (for PD) the patient visited the clinic 3 days and received, next to their RP, a training (1 hour per week) on how to use the exercise-based telerehabilitation service. From the third (for CLBP) or fifth (for COPD) week on, the telerehabilitation service was delivered to the patients as partial replacement; 1 day at the clinic was replaced by 1 day rehabilitation in their own environment. Based on the progression made by the patient the therapist updated the patient's individual tailored exercise program weekly.

Patient and therapist contacted each other weekly by teleconference or meet each other during the remaining 2 days to discuss the rehabilitation progress. Depending on holidays and compulsory days, the program lasted 7 weeks for the CLBP patient and 12 weeks for the PD patient. In total and as such the telerehabilitation service was used for 5-8 weeks [18].

Participants

Patients were recruited by Roessingh Center for Rehabilitation, Enschede, the Netherlands. CLBP and PD patients referred to the physical outpatient RP were asked to participate. Patients were included when they had sufficient understanding of the Dutch language and were aged above 18 years. The appropriate ethics committee approved the study. All patients gave their informed consent prior to participation.

Measurements - actual use of the service

Actual use is being expressed as frequency and duration of use. These data are obtained from the service log files that stores the duration of each single session time between login and logout. These log files were used to get insight in:

- The number of weeks patients used the service and;
- The frequency and duration of use expressed over all weeks together as well as per week.

The sessions smaller than 2 minutes were excluded, because the average duration of an exercise video was 2 minutes and in smaller intervals patients were not able to exercise. The sessions larger than 2 hours were also excluded, because it is unlikely that patients will exercise longer than two hours in one session. It was assumed that in these cases patients forgot to log-out.

Measurements - clinical benefit

Measurement on clinical benefit focuses on complaints (pain or dyspnea) and physical functioning. Complaints and physical functioning were assessed pre-test (in the first

week of the outpatient RP) and post-test (in the last week of the outpatient RP). Patients were asked to rate their level of pain for CLBP patients and level of dyspnoea for PD patients during the previous week. Level of pain and dyspnoea were assessed on a visual analogue scale (VAS) [19,20]. To assess physical functioning the CLBP patient also completed the Roland Disability Questionnaire (RDQ) [21]. In this paper the Dutch version [22] of the RDQ is used. The COPD patient performed a Six-minute walk test (6MWT) [23]. The objective of the 6MWT is to walk as far as possible for 6 minutes on a flat surface.

Data analysis

Demographic characteristics and actual use (frequency and duration of use) are described in terms of mean (SD) or percentage. The compliance to the telerehabilitation service is presented as the percentages of compliant users per week. To investigate the relation between actual use of the intervention and clinical benefit, changes in complaints and physical functioning level were calculated, taking the difference between the pre- and post-test measurements. The correlation between frequency of use, duration of use, Δ VASpainB-T0, Δ VASDyspneaB-T0, Δ RDQB-T0, Δ 6MWTB-T0 were examined. Statistical significant level was set at $p < 0.05$ for all analyses. A standard package (SPSS) was used for statistical analysis.

Results

In total, 104 patients were asked to use the exercise-based telerehabilitation service during their outpatient RP, 81 patients started with the introduction on how to use the exercise-based telerehabilitation service. In total 19 patients dropped out; 8 patients after introduction and 11 during the further treatment weeks. The main reasons for dropping out were discontinuation of the treatment due to an exacerbation (n=8), personal circumstances, such as lack of time or motivation (n=7) and problems with the equipment (n=4). Thus, 62 patients (85%) finished the outpatient rehabilitation using the exercise-based telerehabilitation service. At time of inclusion, the average age of these patients was 49 years (SD 12), the average height was 177 cm (SD 11), the average weight was 88 kg (SD 20) and 63% of the patients in this group were male. There were no significant

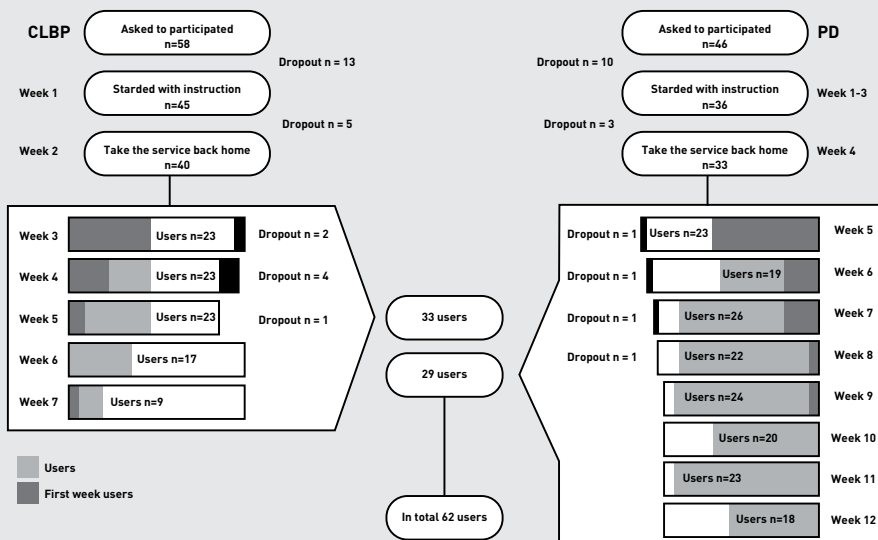
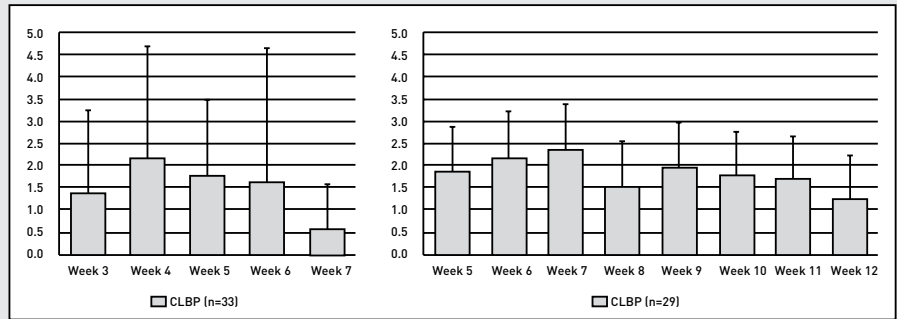


Figure 2: flowchart of recruitment and users over the treatment week for both pathologies (CLBP= chronic low back pain / PD= pulmonary disease)

differences between these patients and patients who dropped out after inclusion (n=19) ($p \geq 0.174$). Figure 2 presents a flowchart of the recruitment and number of patient using the service over the treatment week for both pathologies.

Figure 3a&b: Frequency (counts) of use for CLBP patients (a) and PD patients (b)

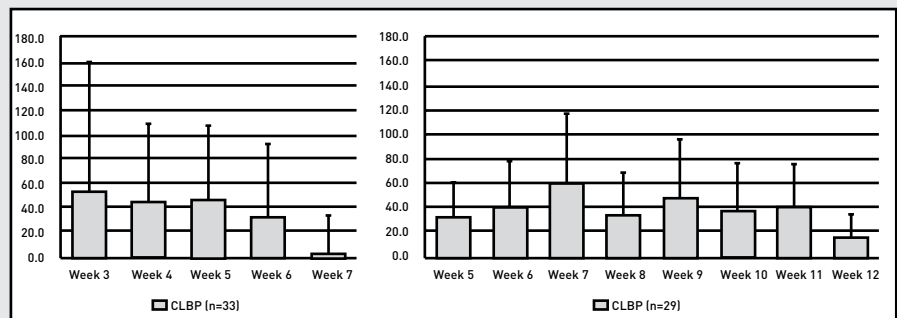


Actual use of the telerehabilitation service

Sixty-one percent of the patients (CLBP 57,5% and PD 66,7%) started to use the telerehabilitation service in the first week when this service was available. Another 21 percent of the patient (CLBP 22,5% and PD 20%) started to use the telerehabilitation service in the second week when this service was available. As the time proceeded the use of the telerehabilitation service (figure 2) dropped. Only 6 patients used the service every week for the whole treatment period.

On average the patients used the telerehabilitation service 10.8 (SD 9.5) times during the weeks of home rehabilitation; CLBP 7.2 (SD 9.5) and COPD 14.8 (SD 10.9) times. This is on average 1.4 (SD 1.3) times a week for CLBP and 1.8 (SD 1.4) times a week for COPD. The frequency of use is presented in figure 3a&b.

Figure 4a&b: Duration of use (minutes) for CLBP patients (a) and PD patients (b)



On average the patients used the telerehabilitation service for 237.8 (SD 226.3) minutes during the weeks of home rehabilitation; CLBP 178.7 (SD 226.3) and COPD 305.1 (SD 208.1) minutes. This is on average 35.7 (SD 37.5) minutes a week for CLBP and 38.1 (SD

26.0) minutes a week for COPD. The duration of use of the service during the weeks of home rehabilitation for both pathologies is presented in figure 4a&b.

Compliance to the telerehabilitation service

For the CLBP patients the service weekly replaced a rehabilitation day of 2 treatment hours (in total 10 treatment hours) and for the PD patient the service weekly replaced a rehabilitation day of 2,5 treatment hours (in total 20 treatment hours).The patients were advised by the therapist to use the service at least once a week. Table 1 shows an overview of the percentages of users that were compliant with home treatment per week, based on frequency of use. Overall, 52-70% of the CLBP patients and 62-90% of the PD patients were compliant to the advice of the therapist. Only two CLPB patients and four PD patients used the telerehabilitation service every week. Because of the aberrant percentage of compliant users in the 7th week of the CLBP patients, this week is considered as an outlier (table 1).

CLBP patients (n=33)	Week 3 55%	Week 4 70%	Week 5 70%	Week 6 52%	Week 7 27%*			
PD patients (n=29)	Week 5 69%	Week 6 66%	Week 7 90%	Week 8 76%	Week 9 83%	Week 10 69%	Week 11 79%	Week 12 62%

Table 1: overview of the percentages of compliant users per week

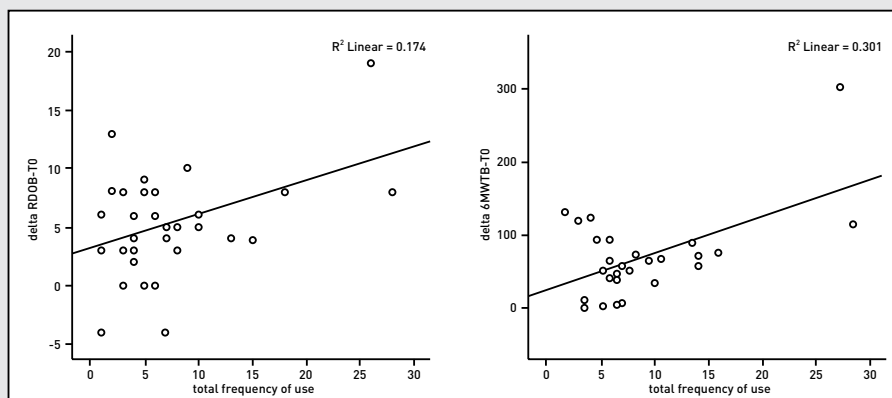
Correlation of actual use and clinical benefit

The relationship between actual use and clinical changes during the rehabilitation period are summarized in table 2. There is a significant correlation between frequency of use and the change (Δ score) in physical functioning score for both pathologies (CLBP: $r=0.41$, $p=0.02$ and PD: $r=0.55$, $p=0.003$)(figure 5a&b). This indicates that the patients, who use the telerehabilitation service more frequently, benefit more from the intervention.

	CLBP patients		PD Patients	
	Δ VAS PainB-T0	Δ RD QB-T0	Δ VAS DyspneaB-T0	Δ 6 MWTB-T0
Frequency of use	0.109 p=0.575 n=29	0.417 p=0.02 n=32	-0.151 p=0.443 n=28	0.548 P=0.003 n=27
Duration of use	0.099 p=0.61 n=29	0.214 p=0.24 n=32	-0.096 p=0.627 n=28	0.142 p=0.480 n=27

Table 2: correlations between actual of use and clinical benefit

Figure 5a&b:
relationship between
total frequency of
use and physical
functioning score



Discussion

The aim of this paper was to examine the use pattern of an exercise-based telerehabilitation service by chronic patients and to examine the association between actual use and clinical benefit experienced by the chronic patients. During the weeks of home rehabilitation 52-90% of the patients used the exercise-based telerehabilitation service and 83% of all patients started to use the exercise-based telerehabilitation service in the first or second week when the service was available. Only 6 patients used the service every week. On average the service was used 1-2 times a week for in total 35-38 minutes for both pathologies which is lower than the time that is replaced from rehabilitation at the rehabilitation center.

Possible reasons for this could be related to both the technology used and the human side of implementation. Focusing on the technology used the level of maturity could be insufficient, resulting in a low degree of user-friendliness of the service. In an earlier paper it was shown that usability of the service was sufficient (system usability scale score of 71.2 (SD 15.0; n=47) [18], however, it was concluded that there is room for improvement of the technology used. Improvements that might further enhance the patients motivation to use exercise-based telerehabilitation services and by this, enhance compliance are modules that give patients insight in their health status over time, such as patient reported outcome measures [24] and ambulant technology that allows objective monitoring and feedback during everyday life activities [25,26]. In addition gaming technology could increase the attractiveness of exercise-based telerehabilitation services while gaming technology is hypothesised to distract patients from their complaints and make exercising fun [27,28].

Another explanation could be that the advice of the therapist concerning use was not concrete or convincing enough with the result that patients are not aware enough about the added value of extra home training. The only instruction given to the patients was that patients should use the service at least once a week. It could be that patients consider the two days of rehabilitation sufficient and that they were not motivated enough (by therapist or technology used) to use the service on a weekly base or more frequently. For further implementation patients also need to be informed about the relevance of intensive use (frequency and duration) of the service.

Results show that when a telemedicine service is delivered of chronic patients as a partial replacement of face to face physical rehabilitation a higher frequency of use was associated with higher outcome on physical functioning. In other words, patients who use the telemedicine service more frequently have a better change on the improvement on physical functioning. As already stated by Huis in 't Veld et al., 2010 [16] and Rho et al., 2014 [17]. Given the results of these papers it can be stressed that the actual use of a telemedicine service should be taken into account when studying its outcome. Especially when the telemedicine service is delivered to the patient as a partial replacement of a conventional treatment with the intention to retain effectiveness and to lower healthcare costs. In clinical papers on the evaluation of telemedicine services the analyses are mostly based on intention to treat. However we recommend performing a protocol analysis next to an intention to treat analyses to obtain evidence of the effectiveness of a telemedicine service. Telemedicine services have the ability to give insight of the actual use of the service and are therefore suitable to investigate the dose-response relationship of these services; an interesting topic of further research.

In conclusion, chronic patients do use a telerehabilitation service as partial replacement of their face-to-face RP. Most patients used the service weekly, but the duration of use was lower than the time that was replaced. In addition, there is a significant association between the amount of use and clinical benefit. Therefore the actual use of a telemedicine service should be taken into account when studying its outcome.

Acknowledgments

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Nintendo GAME BOY™

SELECT

START

B

A



CHAPTER 7

First evaluation of a serious exergame for patients suffering from chronic pain

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Kaufmann H, Hermens HJ, & Vollenbroek-Hutten MMR.
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Abstract

Over recent years, the popularity of videogames has gone beyond the youth and gamers but is slowly entering the professional field of healthcare. Exergames are an attractive alternative to physical therapy. In the PlayMancer project, an exergame for physical rehabilitation of chronic pain patients was developed. The overall aim of the exergame is to improve the patient's physical condition. This exergame is controlled by relevant motions of the patient's body captured by a motion suit, several infrared (IR) cameras and by muscle activation levels. In three different integrated mini-games, the patient can train the following motor skills: walking velocity, overhead reaching and neck mobility. The primary aim of this pilot study was to explore the user experience (usability, satisfaction, level of motivation and game experience) of the participant with the PlayMancer exergame. The secondary aim of this pilot study was to explore the progression of the performed motor skills (walking velocity, overhead reach ability and cervical range of motion) and the clinical changes (to physical condition, disability and pain intensity) brought about in chronic pain patients using the PlayMancer exergame for four weeks. Ten participants participated in this study and completed the four weeks of gaming. Participants rated the usability of the exergames as good (SUS score of 78.5 (SD 9.7; range 60.0-97.5)) and the game motivated all participants to perform their exercises. Participants enjoyed playing and were pleased with both the game environment and the game play. Overall, the participants made a progression in the requested motor skills during the mini-games over the four weeks of gaming, especially those with impairments in the motor skills that the game was intended to improve. In conclusion, the PlayMancer exergame is a potential tool for achieving physical rehabilitation because it motivates patients to perform their exercises and as a result increases their motor skills and physical condition.

Introduction

The growing popularity of video games is not limited to the youth and gamers but slightly enters the professional field of healthcare, such as physical rehabilitation [1]. Serious games have been developed to be played to exercise and train specific motor skills. These are known as exergames and are an attractive alternative to conventional face to face physical therapy [2, 3]. The challenging game environment is considered to be both motivating [4] and distracting [5]. Therefore, the use of games in rehabilitation is believed to improve patients' motivation. This is especially necessary in physical rehabilitation. In physical rehabilitation, patients are required to follow training protocols that are generally perceived as boring due to the high degree of repetition. Therefore, attractive games have the potential to increase the compliance with physical rehabilitation protocols. Furthermore, games challenge participants to play repeatedly to beat their personal best score and thereby increase their treatment intensity. The repetitive nature of games is thought to be a key mechanism in promoting motor skills learning in exergames and have the potential to positively influence physical performance [6, 7] in patients, especially those with significant physical impairments [5].

However, although promising, commercial exergames are designed primarily for entertainment, not specifically to train impaired patients in a professional rehabilitation setting [8]. Practice shows there are several limitations when introducing existing commercial exergames into professional rehabilitation settings. Firstly, commercial exergames are developed for the general public and the norms are matched to the performance of generally healthy gamers. In most cases, it is not possible to change these norms and to personalize the game for an impaired patient. As a result, the game becomes too hard to play which can lead to frustration. Secondly, the level of energy expenditure reported for commercial exergames cannot be compared to levels of energy expenditure typically achieves during physical therapy [6, 7] and the requested motor skills are too general and not sufficiently pathology-specific. Thirdly, the game output of commercial exergames focuses on the game performance; for example, time or a high score, and not the patient's performance on motor skills. Therefore, the physiotherapist cannot monitor the progression of the patient in terms of the performed motor skills.

In the PlayMancer project (FP7-ICT-215839-2007) [9], a exergame (the PlayMancer game) for physical rehabilitation for patients suffering from chronic pain was developed by clinical and technical professionals working together. The overall aim of the game is to improve the patient's physical condition. This exergame is controlled by relevant motions of the patient's body. These motions are captured by a motion suit, several infrared (IR) cameras and by muscle activation levels. Before starting the exergame, the difficulty level of this game is matched to the ability level of the individual patient and individual goals are configured to motivate a progression in terms of the performed motor skills. The technical issues and design of the PlayMancer exergame are also described elsewhere [10, 11].

The progression of the patient can also be monitored by a therapist. In three different mini-games, the patient can train the following motor skills: walking velocity, overhead reaching and neck mobility. This choice of motor skills is not arbitrary. Previous studies have shown that patients with chronic low back pain (CLBP) have lower preferred walking

velocity compared to controls [12] and their physical activity deteriorates due to a lack of use and deconditioning [13]. By walking, CLPB patients can improve their physical condition and so increase their walking velocity. Furthermore, patients with neck/shoulder pain have a reduced ability to reach overhead due to their pain [14]. Besides, patients with neck-/shoulder pain demonstrate a decreased range of motion (ROM) compared to asymptomatic controls [15, 16] and benefit from increasing their neck mobility by exercising.

In the literature, to the author's knowledge, no evaluations of exergames for physical rehabilitation of CLBP patients have been reported. This study is believed to be the first evaluation of a serious exergame for patients suffering from chronic pain and concerns a stage 1-2 evaluation, considering the stage approach of telemedicine evaluation proposed by DeChant et al., 1996 [17]. The primary aim of this pilot study is to explore the user experience - in terms of usability, satisfaction, level of motivation and game experience - of patients playing the PlayMancer exergame. The secondary aim of this pilot study is to explore the progression in terms of the performed motor skills (walking velocity, overhead reach ability and cervical range of motion) and the clinical changes (physical condition, level of disability and pain intensity) brought about in chronic pain patients playing the PlayMancer exergame over four successive weeks.

Materials and Methods

Study design and subjects

Participants were recruited from a local physiotherapy practice and by an advertisement in the newsletter of a patient association for chronic pain patients. Interested participants could contact the researcher and received an information letter concerning the study. Only, those 18 years and older, with low back pain or pain in the neck-shoulder region for at least 12 weeks (without specific pathological causes) were included. Participants were excluded if they had: (1) an insufficient understanding of the Dutch language; (2) visible impairment that inhibits the perception of the screen on which the game is projected on; or (3) receiving (physical) therapy for their physical complaint at the time of the study. The medical ethical committee approved the study. All subjects gave their informed consent prior to participation.

The PlayMancer Exergame

In this game, the participant embarks on a quest to investigate a newly discovered island. After a first inspection, it seems that the island has been previously inhabited. To find out more about the former inhabitants of this island, the player has to play a series of mini-games. By playing these mini-games, artifacts can be collected. Artifacts represent points and these, at fixed quantities, unlocked new information about the island's former civilization. Figure 1 gives an impression of the PlayMancer exergame which consists of three mini-games:

- **Temple of Magupta.** In this mini-game, the subject has to control an avatar, who is walking through a collapsing tunnel. On the way, certain artifacts can be found and collected, while falling debris has to be avoided. Lateral movement of the avatar is controlled by the participant's speech, while the participant's voluntary walking



Figure 1: An impression of the PlayMancer game

velocity on a treadmill controls forward movement of the avatar. The underlying goal of this mini-game is to improve walking velocity and thereby the overall physical fitness of the participants.

- Face of Cronos. In this mini-game, the avatar is climbing a rock face. To help the avatar climb the rock wall, the participant has to reach overhead for a virtual handgrip. Once that goal is reached, the avatar climbs the face. An artifact is earned as a reward for every successful overhead reach. Additionally, the participant receives real-time feedback about the muscle tension in both trapezius muscles. The participant is instructed to relax as quickly and as much as possible in-between movements, in



Figure 2:
The PlayMancer suit

order to gain consciousness about his or her muscle tension. The underlying goal of this mini-game is to improve overhead reaching ability.

- Three wind gods. In this game, the participant has to reproduce sequences of head movements that are shown by three characters. These movements, corresponding to the characters, are flexion-extension, rotation and lateral flexion-extension of the neck. For every successful reproduction of a movement, an artifact is earned as a reward. The overall goal of this mini-game is to improve the participant's neck mobility.

Game input

Relevant motions of the participant's body and muscle activation levels control the PlayMancer exergame. The motion capture (MoCap) system [10] consists of a tight-fitting suit (a jacket, a pair of trousers and a cap) with 36 reflective markers attached to it, to track the participants' movements while playing (figure 2) and eight infrared cameras (IOtracker) [18], positioned at every top and bottom corner of the lab. Furthermore, surface electromyography (sEMG) electrodes (35x26mm Ag/AgCL, tyco Healthcare) are placed on both left and right upper trapezius muscles, on the halfway point of the line between the spinous process of C7 and the acromion. A reference electrode is placed over the spinous process of C7 [19] and the signal is sent to a computer wirelessly.

Treatment protocol

The participants were asked to visit the Roessingh Research and Development (RRD) lab and to play the PlayMancer exergame for four weeks with a (average) frequency of 1-2 times a week. During every game session, a therapist assisted the participant. The first gaming session focused on the calibration of the MoCap system, and help the participant become acquainted with the PlayMancer game. Subsequently, by using the baseline and goal-setting module, the individual baseline values were assessed and individual goals were configured for each motor skill. This module also automatically updates the baseline values of the participant if the participant performs at beyond the baseline level. Then the participant was introduced to the mini-games and the aim of every mini-game was explained. During subsequent sessions, the participants played every mini-game at least three times. Depending on the primary complaint (low back or neck / shoulder pain) or participant's preference a mini-game might be played more than three times. Each gaming session lasted between 45 and 60 minutes.

Measurements – user experience

ISO 9241-210 defines user experience as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service". To assess the user experience of the game there was a focus on usability, satisfaction, level of motivation and gaming experience. The usability of the game was assessed against the System Usability Scale (SUS) [20]. The SUS presented ten statements about the perceived usability of the game. Participants could indicate on a 0 to 4 scale to what extent the presented statements were true for them. To obtain the final SUS score, the sum of the participants' answers was multiplied by 2.5. The SUS score ranges from 0 to 100 (low and high usability, respectively). The English version of the SUS was translated into Dutch, as there was no validated Dutch version available.

The overall satisfaction with the game was assessed by a request to rate the game on a scale from 0 to 10 (low and high usability, respectively) and an open question asking about the overall experience of the game.

The level of motivation was assessed by posing two questions. For the first question, participants rated on a 7-point Likert scale ranging from “demotivating” to “motivating”, their level of motivation related to the PlayMancer game. The second question was answered with yes or no: “Did the PlayMancer game motivate you to perform your exercises?”.

The game experience of the participants during gaming was assessed by the enjoyment, frustration, environment (graphics and sounds) and game play (scenario and rules) scale of the Core Elements of Gaming Experience Questionnaire (CEGEQ) [21]. This questionnaire presents 17 statements. Participants could indicate on a scale ranging from 0 to 7 to what extent these statements were true for them. The summed score per category gave a view of each participant’s overall gaming experience. The English version of the CEGEQ was translated into Dutch, as there was no validated Dutch version available. All the questionnaires were assessed immediately after four weeks of gaming (post-test).

Measurements – game output

The progression on the performed motor skills was assessed by analyzing the game data. After every game session, the game data was saved in a patient specific-folder. In this folder were among others saved the walking velocity (“Temple of Magupta”), the movement time and velocity and 3D wrist position (“Face of Cronos”) and the rotation of the head around the three axes (“Three wind gods”).

Measurements – clinical changes

The physical condition of the participant was assessed by the six-minute walk test (6mwt) [22]. The objective of this test is to walk as far as possible for 6 minutes on a flat surface such as a hallway. During the test, patients were permitted to slow down, to stop, and to rest if necessary.

The subjectively experienced disability of patients with pain was assessed by a generic disability questionnaire, namely the pain disability index (PDI) [23]. The PDI is a self-rating scale. Answers are provided on a categorized 11-point scale with ‘not disabled’ and ‘fully disabled’ at the extremes. In a chronic pain population, the psychometric properties of the PDI appeared to be sufficient [23].

Pain intensity of the back region or neck/-shoulder region was assessed by means of a visual analog scale (VAS) [24]. Participants were asked to rate their experienced level of pain during the last month. The VAS consists of a 10 cm horizontal line with “no pain” on the left and “worst pain ever” on the right extremity of the line. Psychometric properties have proven to be sufficient.

The 6mwt, PDI and VAS were assessed prior to (pre-test) and immediately after four weeks of gaming (post-test).

Analysis

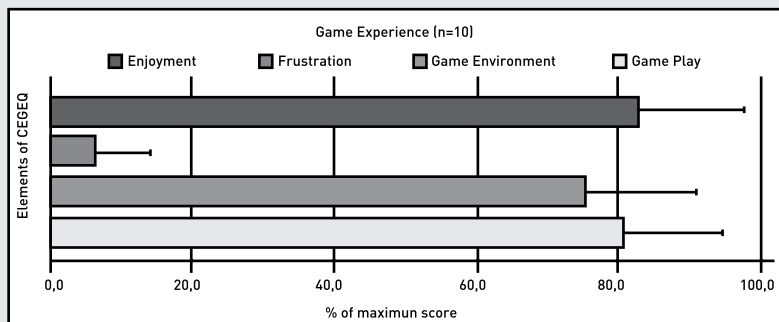
To assess the user experience, the mean scores post-test of the assessed questionnaires were calculated. Because of the pilot characteristics of this study, all participants were asked to play all three mini-games, even if the motor skill(s) requested in the mini-games did not correspond with their complaint(s). For this reason the progression on the performed motor skills of the game are presented separately for the whole group and for the participants with a significant impaired function for these motor skills.

For the “Temple of Magupta” mini-game, the average walking speeds for each game week are presented. The average walking speed was calculated over the total “Temple of Magupta” mini-game, per session. For the “Face of Cronos” mini-game the average overhead reaching heights, wrist position, for each game week are presented. The wrist position was determined as the maximum wrist height per movement. This position was relative to the shoulder. The maximum height of every reach was defined as the point, between the start and end of a movement, in which the velocity of the wrist was 0 m/s. For every game session, an average value was calculated to describe the reaching heights. For the “Three wind gods” mini-games, the average range of motion in degrees of the cervical axial rotation from left to right (no-movement) for each game week are presented. For every game session, an average value was calculated to describe the cervical range of motion (CROM). Data processing and calculation were done using Matlab software (version R2008b, Matworks). At a group level, the overall clinical effect of the PlayMancer game over time (pre-test versus post-test) on physical condition, disability and pain intensity was analyzed using a paired non-parametric test (Wilcoxon). SPSS 19.0 was used for statistical testing. Alpha was set at 0.05 to test for statistical significance.

Results

Ten participants (2 male and 8 female) participated in this study. All participants met the predefined inclusion criteria and completed the four weeks of gaming. The mean age was 54.9 years (SD 11.8; range 27-68). Four of the subjects were employed and worked for 28-40 hours per week. Six of the subjects reported primary neck-/shoulder complaints and four subjects reported primary low-back complaints.

Figure 3: Overview of overall scores on CEGEQ subscales of enjoyment, frustration, game environment and game play.



User experience

The usability of the PlayMancer exergame was as rated good (SUS score ≤ 71.4 [25]), mean SUS score of 78.5 (SD 9.7; range 60.0-97.5).

The overall satisfaction with the PlayMancer exergame was high. The participants gave the exergame an average rating of 7.6 (SD 0.7; range 6-8) out of 10. Four participants responded to the open question about the overall experience of the exergame. The participants stated: ***“The game distracted me, I was less aware of the pain and therefore I was able to relax and play the game” (participant no3), “I liked to play the game” (participant no4), “The Temple of the Mapugta mini-game I enjoyed most, the other two games I enjoyed less. These mini-games were insufficiently stimulating for me” (participant no5) and “Playing the game caused distraction from my pain, therefore I was able to execute the requested exercises better; I walked longer and stretched my neck more” (participant no9).***

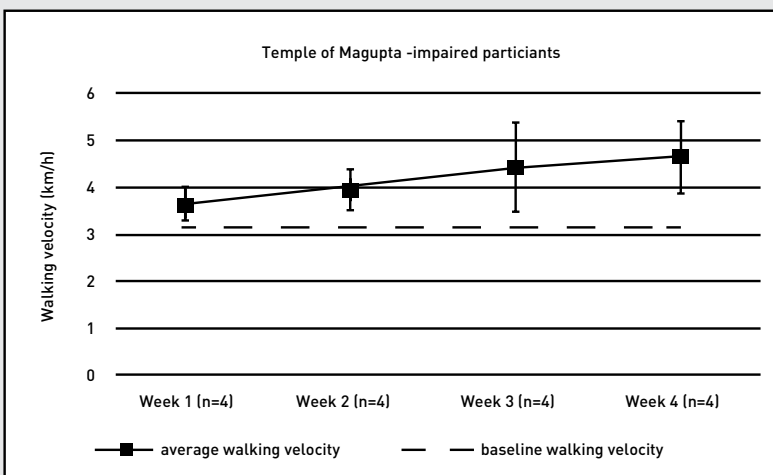
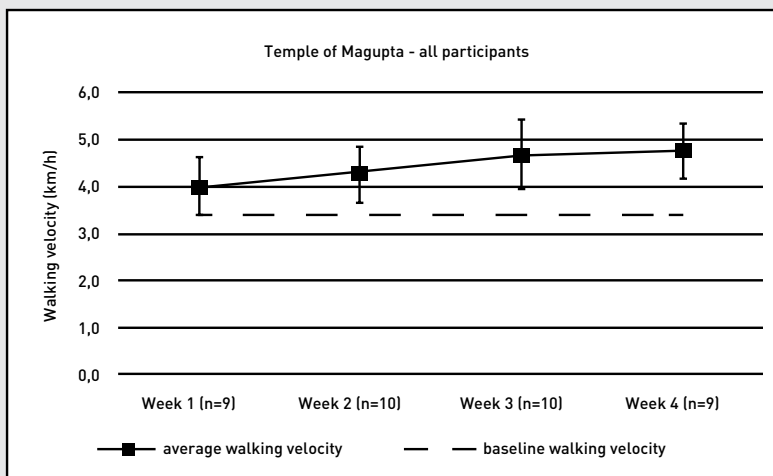


Figure 4a & b: Average walking velocity of all participants (a) and the participants with an impaired walking velocity (b) during the “Temple of Magupta” mini-game.

Nine out of ten participants found the PlayMancer exergame a motivating exergame; one patient gave a neutral answer. All the participants found that the exergame motivated them to perform the requested motor skills.

The outcomes on game experience are presented in figure 3. Participants enjoyed playing the PlayMancer exergame and considered that it did not lead to frustration. The high scores seemed to indicate that the participants were satisfied with the game environment (graphics and sounds) and game play (scenario and rules).

Progression on performed motor skills: The results on the progression in performed motor skills (walking velocity, reach height and CROM) are presented firstly for the whole group and secondly for those participants with relevant impairment.

Walking Velocity

Group: The average baseline (voluntary) walking velocity was 3.4 km/h [range 2.5-4.5]. In the first week, the average walking velocity during gaming was 4.0 km/h [SD 0.6; range 3.2-5.2] and in the final week the average walking velocity during gaming increased to 4.8 km/h [SD 0.6; range 3.7-5.6] (figure 4a).

Impaired participants: Four participants (no2, no3, no4, and no10) had an impaired walking velocity of 4.2 km/h or less on the 6-mwt performed pre-test [26]. Looking at their walking velocity during playing the game, game data showed an average baseline walking velocity of 3.1 km/h [range 2.5-3.5]. In the first and final weeks these values were 3.6 km/h [SD 0.3; range 3.2-4.0] and 4.6 km/h [SD 0.8; range 3.7-5.3], respectively (figure 4b).

Reach heights

Group: The average baseline reach heights for the left and right arms were 2.05 meters [range 1.91-2.16] and 2.05 meters [range 1.93-2.14], respectively. For the left arm, the average reach height in the first week of gaming was 2.08 meters [SD 0.03; range 2.02-2.13]. In the final game week, the average reach height of the left arm increased to 2.10 meters [SD 0.02; range 1.98-2.15]. For the right arm, the average reach height in the first week was 2.05 meters [SD 0.02; range 1.85-2.15]. In the final game week, the average reach height of the left arm increased to 2.10 meters [SD 0.01; range 2.03-2.17] (figure 5a).
Impaired participant: Only one participant (no2) had in the first week a discrepancy of overhead reach height between the left and right arm. The reach height of the right arm was 23 cm under the reach height of the left arm. The reach height of the right arm of this subject in the first week was 1.85 meters and this increased to 2.12 meters in the final week (figure 5b).

Cervical range of motion (CROM)

Group/impaired participants: During the first week, the CROM for cervical axial rotation, from left to right, during gaming was 129.1° (SD 6.8; range 119.9°-138.5°). The CROM for cervical axial rotation, from left to right of healthy participant is 151.7° [16], all participants had an impaired CROM (CROM ≤ 151.7°. During the final gaming week, the CROM increased to 139.5° (SD 16.1; range 121.0°-161.2°) (figure 6). During the final week, three participants (no2, no4 and no9) reached the CROM cut-off point (> 151.7°) for healthy participants [16].

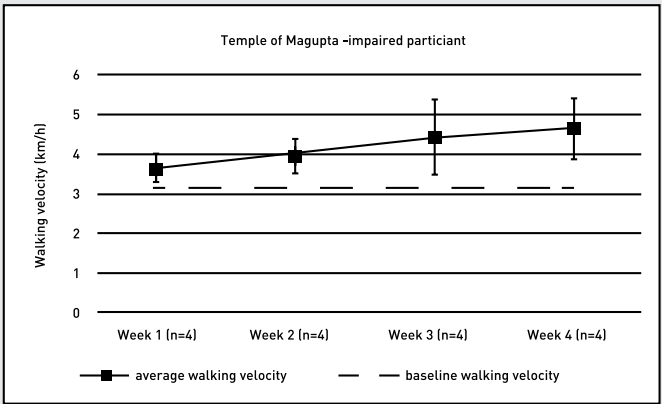
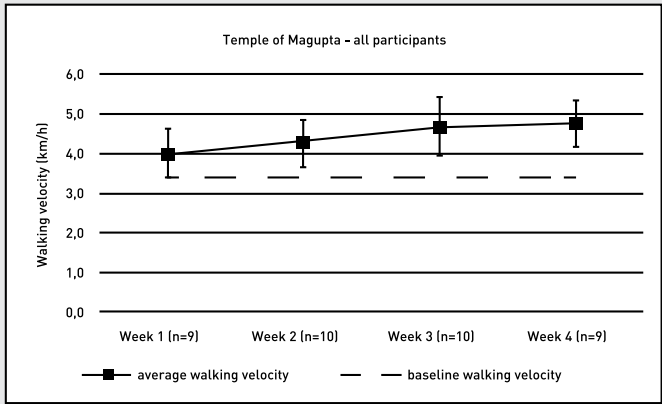


Figure 5a&b: Reach height overhead reaching of all participants (a) and the participant with an impaired reach height (b) during the "Face of Cronos" mini-game.

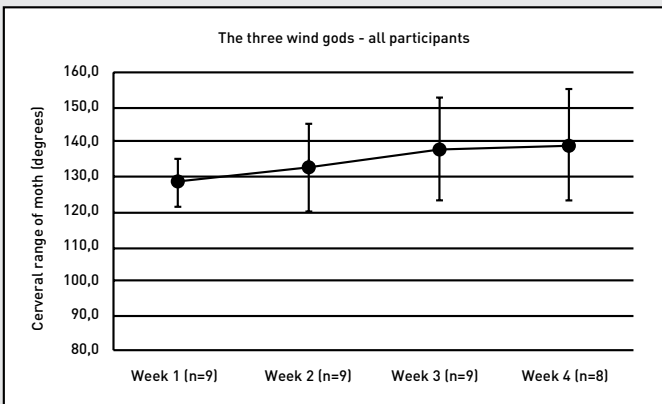


Figure 6: Cervical range of motion of all participants (all impaired CROM) during the "Three wind gods" mini-game.

Clinical effectiveness: The physical condition of the participants was assessed by using the 6mwt. Pre-test, the average walking distance was 445 (SD 77) meters. At post-test, the average walking distance had increased by 20 meters to 465 (SD 46) meters. However, this difference is not significant ($p=0.212$). The PDI decreased by almost one point at post-test. The difference between pre-test and post-test scores for disability are not significant ($p=0.505$). After four weeks of gaming, the perceived pain intensity of the participants decreased from 59 (SD 21) on a 100 mm VAS to 50 (SD 24) to 50 (SD 24) (Table 1). Again this average difference is not significant ($p=0.284$).

Table 1: Outcome on pain intensity, pain disability and six-minute walk test. There were no significant differences between pre-test and post-test scores ($P \geq 0.212$)

	Mean (SD)	
	Pre-test	Post-test
Pain intensity	59 (21)	50 (24)
Pain disability index	27.2 (13.5)	26.3 (15.0)
Six-minute walk test	445 (77)	465 (46)

Discussion

This pilot study focused on a first evaluation of the PlayMancer exergames for patients suffering from chronic pain. The primary aim was to explore the user experience of the participants with the PlayMancer exergame. The secondary aim of this pilot study was to explore the progression in terms of the performed motor skills (walking velocity, overhead reach ability and cervical range of motion) and the clinical changes (physical condition, disability and pain intensity) brought about in chronic pain patients using the PlayMancer exergame for four weeks. Participants experienced the PlayMancer exergame as positive. They rated the usability of the exergames as good and the exergames clearly motivated participants to perform their exercises. Furthermore, participants enjoyed playing the exergame and liked the game environment and game play. Despite the short training period, overall the participants made a progression in terms of the requested motor skills in the mini-games during the four weeks of gaming, especially those participants with impaired motor skills. After four weeks of gaming, generally participants were capable of walking faster, reaching higher and experienced an increase in neck mobility.

Exergames, such as the PlayMancer exergame, encourage participants to perform their exercises. Therefore, they have the potential to overcome the generally low conformance with of home-based exercise programs. Home-based exercise programs (for example, those supported by paper or telephone contact) are known to be effective [27] but the overall low conformance with such programs remains problematic [28]. It is known that the conformance to a rehabilitation program has a positive effect on clinical outcomes [29]. Therefore, conform patients benefit most from a rehabilitation program. Another positive aspect of the PlayMancer exergame is the availability of game data. This data provides the therapist with detailed information on the progression of a patient in terms of the various trained motor skills. By using the available game data, the therapist can better align the game session to the needs of the individual patient and the transparency of the treatment is increased, which matches in the current trend in healthcare. However, none

of the commercially available exergames currently provides the healthcare professional with this type of game output.

Previous randomized controlled trials (RCT) have shown the potential of games for helping to rehabilitate stroke patients [30-32], patients with acquired brain injury [33] and young patients with cerebral palsy [34]. However, much remains unknown about the impact of a serious game when used in rehabilitation [35]. Clinical trials, to test the benefits of exergames in rehabilitation, are necessary before such games are incorporated into rehabilitation programs [36]. This pilot study is a first step towards the implementation of exergames in the physical rehabilitation of chronic pain patients. For the first evaluation of the PlayMancer game into the framework for telemedicine evaluation, proposed by DeChant et al., 1996 [17] was used. In line with this framework, the presented pilot study is a stage 1-2 evaluation. Following DeChant et al., 1996, the evaluation of an application starts with an evaluation of the technical efficacy (accuracy and reliability) of the application and an evaluation of the primary objective of the application in terms of access, quality or cost (stage 1-2). During the subsequent deployment, a comprehensive evaluation is necessary, using multiple endpoints such as the quality, accessibility and costs of this healthcare approach (stage 3). The final step in the evaluation of an application is to examine whether the overall evaluation of an application in one system, can also apply in other settings (stage 4) [17]. Even though this framework is designed for telemedicine evaluation, it can be adopted for evaluation of serious games in healthcare. This pilot study and framework can help other researchers to organize the evaluation of their serious (exer)games in a clinical setting. Although the sample size of this study is low and there was no control group, it still extends the knowledge about the use of exergames in the physical rehabilitation of chronic pain patients.

By playing the PlayMancer game, participants made a progression in the requested motor skills. However, it is unknown if these progressions are clinically relevant and comparable to progressions made during a conventional physiotherapy treatment. Therefore, a next step in the evaluation of the PlayMancer game is to compare the PlayMancer exergame with conventional physiotherapy for patients suffering from chronic pain and to compare them on clinical benefit, user experience and costs (stage 3).

The current version of the PlayMancer game only involves three mini-games and an increase of the number of mini-games would be desirable. With more mini games available, a game session with the PlayMancer exergame could be better adjusted to the rehabilitation goals of the individual patient and that patient's treatment protocol can be refined. The duration of the treatment protocol in this study is four weeks. Subjects visited the RRD lab to play the PlayMancer game 1 or 2 times a week over four weeks. Because of the positive effects of intensity, frequency and duration of training on physical fitness [37], it can be assumed that extending the treatment protocol (for example, duration: six weeks instead of four weeks and frequency: at least twice a week) could further positively influence the outcome. A final suggestion is to adjust the game for remote physical rehabilitation. In this study, participants were dependent on the availability of the therapist and the RRD lab to play the game. In a previous study, the Microsoft Kinect was integrated and tested as an alternative low-cost MoCap system. In this setting, two of the PlayMancer mini-games (The "Temple of Magupta" and the "Face of

Cronos") could be controlled by the requested motor skills [10]. Our existing knowledge about telerehabilitation suggests that the PlayMancer exergame has the potential to increase the quality and accessibility of healthcare and perhaps to lower costs. Patients can play the exergame during a self-scheduled time span in their own environment. This would fit with the current trend of self-management of the patient [38].

To conclude, the PlayMancer exergame has been shown to be a promising tool for achieving physical rehabilitation because it motivates patients to perform their exercises and as a result, their motor skills and physical condition both improve.

Acknowledgments

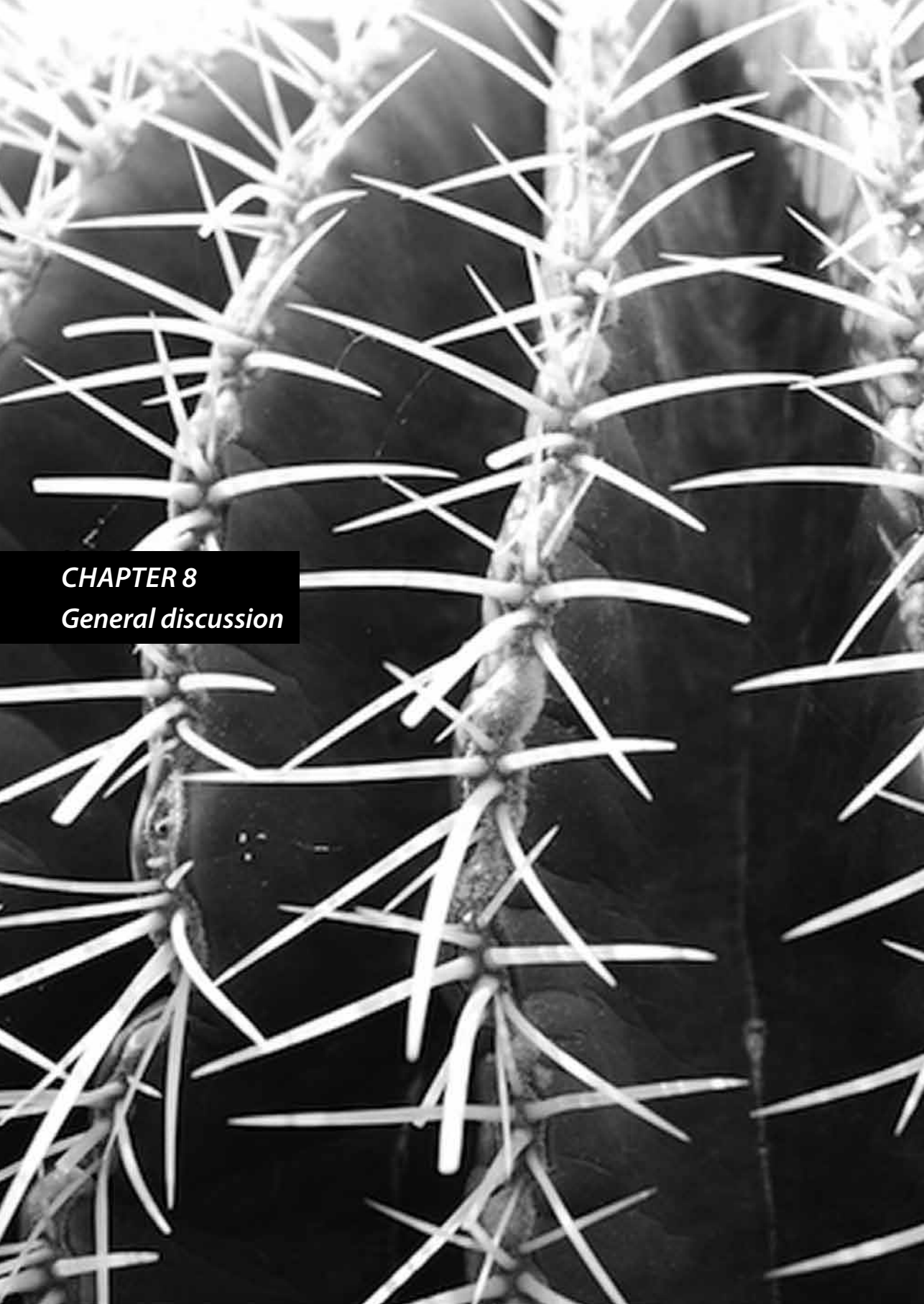
Special thanks go to Michiel Minten for his assistance in carrying out this study and we want to thank Cris Voldum, Jens Juul Jacobsen, Jeppe H. Nielsen and Jørgen Krabbe from Serious Games Interactive for the implementation of the game. This work was funded by the European Union within the PLAYMANCER project (FP7-ICT-215839).

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CHAPTER 8

General discussion



Despite the huge potential of telemedicine services (increasing accessibility of care, increasing quality of care and lowering of healthcare costs), its implementation in daily clinical practice is very limited and most services fade away after a project or pilot phase [1-3]. The aim of this thesis has been to contribute to knowledge concerning the added value of telemedicine services for physical rehabilitation. For this, two state of the art evaluation studies of telemedicine services for physical rehabilitation (chapter 2 and 3) have been performed and in addition, the actual use of these telemedicine services and its association between actual use and clinical benefit have been addressed (chapter 5 and 6).

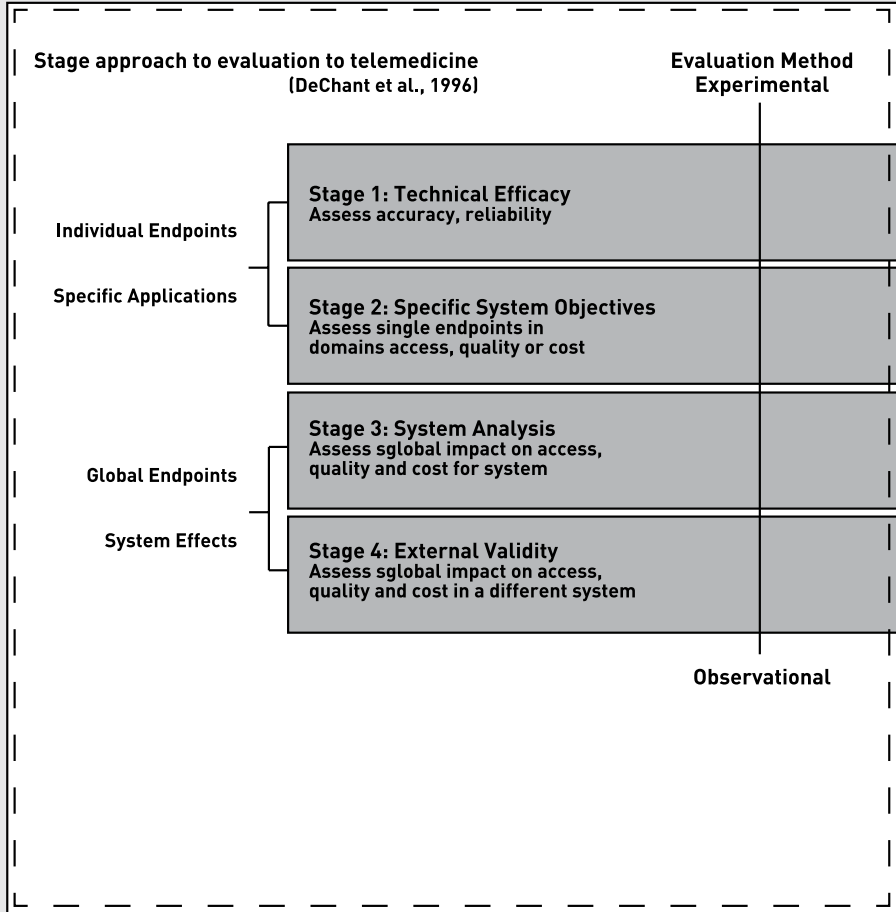
The evaluation of telemedicine services for physical rehabilitation

The evaluation study of this thesis (chapter 2 and 3) applied the framework of Dechant et al., [4]. This so-called, stage approach to evaluation of telemedicine advises, to tailor the type of assessment to the development cycle of the technology. This is important as methods of technology assessment that are appropriate for mature technologies are often not suitable for emerging ones or are even worse and may risk stifling their development with premature negative conclusions. Roughly, the “Dechant” framework differentiates between telemedicine evaluations at application (stage 1 – 2) and global levels (stage 3 – 4). The first two stages concern small scale studies and the outcomes used are focused and its results are merely used to further improve the technology. Stage 3 and 4 concern more comprehensive larger evaluation studies and multiple outcomes (access, quality and cost) are applied. Aligning to this framework, the evaluation studies performed in this thesis were at the stages 3 and 4 level. The study into the myofeedback-based teletreatment was (chapter 2) evaluated as a stand-alone service and the potential added value evaluated increased accessibility and quality of care and decreased healthcare costs. Considering that accessibility patients were satisfied (chapter 4) and they experienced a reduction in travel time (chapter 2) the myofeedback-based teletreatment was as effective as usual care (chapter 2 [5]) in a heterogenic population and a positive business model was found [6]. The exercise-based telerehabilitation service was (chapter 3) evaluated when implemented as a partial replacement of a face-to-face rehabilitation program. After the introduction weeks, for patients the number of visits to train at the rehabilitation center was lowered from three times a week to two times a week and patients were asked to rehabilitate in their own environment at least once a week, by using the exercise-based telerehabilitation service. Considering this implementation, the potential added value of this treatment was to lower the time invested by the professional, while delivering treatment at the same quality. Results indeed confirmed this hypothesis (chapter 3).

Results of the state of the art paper presented in this thesis (chapter 4) shows that the stage approach to the evaluation of telemedicine [4] is rarely applied in other evaluation studies so far. Worse, the evaluations studies are not adequately performed and no uniform conclusion can be drawn about the potential added value of telemedicine services [7, 8]. A possible explanation for this and steps forwards in showing the added value might be facilitated by a more detailed evaluation framework. A framework that provides concrete guidance for those working on this research field, starting from the “DeChant” framework extended by lessons learnt from the studies performed in this thesis over four different topics:

1. On the evaluation objectives. Clear evaluation objective per stage are needed to specify a focus of the evaluation. The objective of DeChant et al., [4] are broad and not specific enough. Taking into account the development cycle of the technology used in every stage, evidence is gained to take the next step to further the implementation of the telemedicine service. The framework describes per stage the focus of the evaluation objectives.
2. On the evaluation context. At this moment telemedicine services when evaluated are rarely implemented in daily clinical practice but evaluated as standalone services (chapter 4). At some point, these services should be implemented in daily clinical practice, to gain insight into the impact of the telemedicine service on a health delivery system. The framework describes per stage the preferred approach to how the telemedicine service should be implemented in daily clinic practice (service configuration).
3. On evaluation methodologies. Dechant et al., [4] suggests experimental methods in the first stages and observational methods in the final stages. Especially "observational methods" for stage III and IV need to be better specified as Dechant et al., [4] states that randomized designs are difficult to implement in these stages. The framework suggests potential evolution methodologies per stage.
4. On evaluation endpoints. Evaluation endpoints should focus on access, quality, and cost [4]. These are experienced to be broad. The state of the art paper (chapter 4) presented in this thesis showed especially, that potential added value of telemedicine services and by this the evaluation endpoints, depend on the technology used, the clinical purpose for which the telemedicine service is being used and how the telemedicine service is implemented in daily clinic practice (service configuration). The framework describes the focus of the evaluation endpoints per stage.

Starting with these 5 topics, a new evaluation framework has been developed that describes how evaluation can best be focused by addressing each stage of the evaluation objectives, evaluation context, evaluation designs and evaluation endpoints. These aspects are considered essential to prepare an adequate evaluation of telemedicine services. The framework is presented in figure 1.



Evaluation objective	Evaluation context	Evaluation design	Evaluation Endpoints
<ul style="list-style-type: none"> • Usability and feasibility of the technology 	<div style="border: 1px solid black; padding: 5px; margin-bottom: 5px; text-align: center;">Stand alone</div> <div style="border: 1px solid black; padding: 5px; text-align: center;">Embedded in daily clinical practice</div>	<ul style="list-style-type: none"> • Case Studies 	<div style="display: flex; justify-content: space-between;"> <div style="width: 20%; background-color: black;"></div> <div style="width: 60%; background-color: #cccccc;"></div> <div style="width: 20%; background-color: #cccccc;"></div> </div>
<ul style="list-style-type: none"> • Working mechanism and potential effect 		<ul style="list-style-type: none"> • Singlecase design • Factorial design • Small cohort studies 	<div style="display: flex; justify-content: space-between;"> <div style="width: 20%; background-color: black;"></div> <div style="width: 60%; background-color: black;"></div> <div style="width: 20%; background-color: #cccccc;"></div> </div>
<ul style="list-style-type: none"> • Effectiveness • Adoption 		<ul style="list-style-type: none"> • cmRCT • Large cohort studies 	<div style="display: flex; justify-content: space-between;"> <div style="width: 20%; background-color: black;"></div> <div style="width: 60%; background-color: black;"></div> <div style="width: 20%; background-color: #cccccc;"></div> </div>
<ul style="list-style-type: none"> • Adoption • Business models 		<ul style="list-style-type: none"> • Large cohort studies 	<div style="display: flex; justify-content: space-between;"> <div style="width: 20%; background-color: black;"></div> <div style="width: 60%; background-color: black;"></div> <div style="width: 20%; background-color: #cccccc;"></div> </div>
			<div style="display: flex; justify-content: space-around; text-align: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">Service configuration</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">Clinical purpose</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">Technology used</div> </div>

Figure 1: The specification of the stage approach to evaluation of telemedicine [4].

Stage I

The first stage of telemedicine evaluation focuses on the feasibility and usability of the technology used in an experimental design with a small number of subjects or even case studies. This type of evaluation design allows researchers to gain detailed information which can be used for further improvement of the telemedicine service. The telemedicine service is evaluated as a stand alone service and evaluation endpoints focus on feasibility and usability of the technology used.

Stage II

The technology used in the second stage is stable and evaluation is focused on gaining an initial idea about the potential added value for clinical practice and possible working mechanisms. For this, evaluation can be performed using the telemedicine service as a stand alone service. Designs that can be used focus on studying processes in often small group of subjects rather than on examining the effectiveness. Suitable designs are: 1] cohort studies with a small sample size ($n < 50$); 2] single-case design (or $N = 1$ designs) that are shown to be suitable, useful and feasible to assess the natural history of relationships between treatment processes and outcomes within individuals [9]; 3] factorial designs that enables a researcher to simultaneously evaluate two treatments and their interaction. Besides being efficient, factorial designs are an effective way to examine interaction effects [10, 11]. By using this design the potential effect of various modalities of the telemedicine service could be compared in one study. The evaluation endpoints in this stage should focus on the potential added value of the telemedicine service mapped on both the technology used and the clinical purpose that is supported.

Stage III

This stage starts when earlier studies indicate that the telemedicine service has potential and focuses on showing the effectiveness of the telemedicine service and/or adoption of the service by its end-users. In order to identify these aspects, it is important that the telemedicine services are evaluated in the way they will be implemented in daily clinical practice. Although, randomized controlled trials (RCTs) are considered the gold standard for evaluating the safety and effectiveness of medical interventions their characteristics do not fit well with the evaluation of telemedicine services [8]. An alternative for a conventional RCT might be the "cohort multiple randomized controlled trial" (cmRCT) being introduced by Relton et al., [12]. This design tackles some of the problems associated with pragmatic trial designs. The key features of this design are: 1] recruitment of a large observational cohort of patients with condition of interest; 2] regular measurement of outcomes for the whole cohort; and 3] capacity for multiple randomised controlled trials with new releases of telemedicine technology over time. In addition, the cmRCT design aims to replicate routine healthcare in the real world. For each randomized controlled trial, information from the cohort is used to identify all eligible participants. Some eligible participants are randomly selected and offered the intervention. Data on participants who are not willing to participate provides information on the acceptability of the intervention. The evaluation endpoints at this stage should not only focus on a previously defined value expected for each technology used and the clinical purpose that is supported but also take into account the way the telemedicine service is being implemented in daily clinical practice (service configuration).

Stage IV

The fourth stage evaluation elaborates the adoption as addressed in stage III. To ensure further implementation, involvement of every stakeholder (healthcare professionals, patients, technology providers, insurance companies and policy makers on a local and national level) is important. This means that evaluation here should focus on the business models and concrete business cases. Without information on the cost and effectiveness of telemedicine services, decision makers run the risk of introducing services that are not cost-effective for society [13]. This evaluation can only be performed in an adequate way when the service is implemented in daily clinical practice as only in this cases the true added value can be evaluated. The studies performed in this stage are large-scale cohort studies ($n \geq 50$) [14]. As addressed in stage III the evaluation endpoints in this stage should focus on the expected value of the telemedicine service depending on the application that is being used (technology used and clinical purpose) but also on the way it has been implemented in daily clinical practice (service configuration).

This framework does not suggest that stakeholders should only be involved in stage IV. Stakeholder involvement is important in every stage of telemedicine services [15]. In recent years it is common that technical developers and end-users (health-care professionals and patients) of telemedicine services are working together to develop these kind of services. By this co-creation the transition that is needed to develop from an initial idea of a telemedicine service to the embeddement of this service in daily clinical practice is minimized. This iterative process of telemedicine services enables end-users to give their opinion concerning the technology used in an early stage of the design process. This same co-creation is desirable for the evaluation of a telemedicine service. The presented framework as a response on the shortcoming to the stage approach to evaluation of telemedicine [4] for the evaluation of current telemedicine should of course be further validated.

The relevance of use

It is known that compliance, defined as the extent to which a patient's behavior coincides with the healthcare professionals advice [16] to exercise treatment, has a positive effect on clinical outcomes [17]. Besides, in face-to-face physical rehabilitation there is increasing evidence that intensive programs (high use levels) are more effective on health outcome than programs with a lower level of intensity (low use levels) [18]. As such it makes sense to test the hypothesis that for telemedicine higher use is also related to better outcomes. In addition, real use is a sort of indication to whether the telemedicine service is really adopted. Research focusing on the use of telemedicine services is mostly limited to the acceptance of technology and the intention of end-users (patients and healthcare professionals) to use the telemedicine service in future. Models underlying this research as the technology acceptance model (TAM) [19, 20] and the unified theory of acceptance and use of technology (UTAUT) [21], assume that acceptance of technology and the intention to use the telemedicine service in the future can be predicted with determinants as perceived usefulness and perceived ease of use. However they do not really address actual use and besides this, these models are not extensively validated for telemedicine.

In chapter 5 the Technology Acceptance Model (TAM) is used to, among others, investigate whether determinants as “ease of use” and “usefulness” are also related to the actual use of the myofeedback-based teletreatment. Results of chapter 5 show that there is no significant correlation between these determinants and actual use. So, despite end-users having the intention to use the service they do not put this intention into practice. Probably, end-users find it very difficult to translate their good intentions into behavior. This phenomenon is called the intention-behavior gap. From behavioral science literature it is known, that intentions account for less than 30% of the actual behavior [22, 23] which means that someone’s behavior is mostly influenced by other factors. One way to bridge the intention-behavior gap, and to enhance the likelihood that intentions are translated into behavior, is by formulating very specific and detailed intentions, so-called implementation intentions [24]. These intentions specify exactly when, where and how the behavior will be performed, as well as what will be done to overcome potential barriers. Translating this to the home based exercise program as being researched in this thesis means that patients plan exactly on which day and time they use the service at home and how long they exercise.

Chapter 5 and 6 of this thesis shows that increasing the actual use of a telemedicine service by implementing strategies are important. There is an significant association between actual use and clinical benefit. For the myofeedback-based teletreatment there was a significant association between the total hours and clinical benefit in pain relief (chapter 5). For the exercise-based telerehabilitation service there was a significant association between the total frequency of use and clinical benefit in physical function. (chapter 6). The actual use data of the myofeedback-based teletreatment service (chapter 5) showed that participants used the service for a sufficient amount i.e. the minimal hours that were prescribed. However, the actual use (assessed as the number of hours and number of days) decreased during the four weeks of treatment period. For the exercise-based telerehabilitation service (chapter 6) the average use was 1-2 times a week in terms of frequency and a total of 35-38 minutes per week in terms of duration. Concerning the decrease of actual use over time, there are various explanations. Firstly, it can be due to the fact that patients get used to using the telemedicine service and get familiar with the exercises. In this case patients do not need the service anymore to exercise independently in their own environment. This is of course a positive development as it really means that a patient is able to self-manage his disease and sustain his healthy behavior but so far this is not known. Secondly, it could be possible that the gained experience diminished and further use does not increase their functional capacity. Thirdly, it might be related to a decreased motivation of the patient over time. The patient in the first weeks are motivated but after those first weeks it becomes hard to be motivated and use the service. The aim of the exercise-based telerehabilitation service was to motivate patients to rehabilitate in their own environment and to execute their exercises at home. Only a fifth of the patients stated that the service motivated them to exercise (chapter 3). This means that better motivational strategies in telemedicine are needed.

In literature various examples of these kinds of strategies are being described for instance in the field of pervasive health technologies and gaming technologies. Examples of pervasive health technologies are ambulant technology that allows objective monitoring

and feedback during everyday life activities or motivating messages based on a patient's compliance to exercises or progress being made. These technologies have the ability to increase patient awareness, for example, their level of activity, and coach patients to balance or increase this level of activity based on norm data or a personalised goal [25-27].

Gaming technology is hypothesized to distract patients from their complaints [28], to make exercising fun [29], and by this increases the compliance and actual use. A first explorative study on gaming technology is performed in chapter 7. In this chapter a gaming environment installed in a lab setting has been evaluated. Over a period of 4 weeks chronic pain patients were invited to play an exergame. By wearing a suit with markers and tracking technology the movements of the patients were mirrored to the exergame. Given the results of chapter 7 it can be concluded that gaming technology could be a promising tool for achieving physical rehabilitation because it motivates patients to perform their exercises. As a result their physical capacity could be improved (chapter 7). More expensive studies are needed to sustain these results.

Next to exergames, gamification might offer a great potential to motivate end-users. Gamification is defined as the application of knowledge from game design to non-game fields [30]. Gamification is utilized in many different areas and mainly known for its success in brand promotion and customer loyalty programs, which focus on short-term engagement through extrinsic rewards. For telemedicine services these principles of gamification should be further explored and developed in such a way that they also address the intrinsic motivation of the users for instance by taking into account their personality and game preferences. In this way the chance of long term adherence is expected to be improved.

Limitations

In this paragraph some of the limitations of various chapters of this thesis will be emphasised. Firstly, the sample size of the intervention groups in both evaluation studies (chapter 2 and 3) were, based on the sample size calculation, sufficient. However, a control group with a sufficient size was difficult to achieve for the exercise-based telerehabilitation service that was implemented as partial replacement (chapter 3).

Secondly, the implementation of the exercise-based telerehabilitation service as partial replacement of the conventional rehabilitation program (chapter 3) also resulted in a sub optimal study design that could have biased the results. The patients were not randomized for the intervention or control group which could result in a selection bias. At the outset both groups were similar on assessed demographic characteristics, but other unknown characteristics could have influenced the effect. In addition, all patients independent of their preferences for the use of technology or non use of the technology were included in the intervention group. It can be hypothesized that this might have influenced the added value in a negative way as some patients were quite averse to it. It would be better to take these preferences into account during the allocation procedure as is done by a patient preference design [31].

Thirdly, in literature there is no guideline to how to assess actual use of telemedicine

service. In chapter 5 actual use was defined as total amount of use which was determined at the time the technology ran. Based on log data this was calculated and logs smaller than 5 minutes and with no EMG data were deleted. In chapter 6 actual use was defined as the total frequency and duration of use, determined by the login and logout moment of the patient. The time between log in and log out was considered as the duration of use. Intervals with duration of 2 hours or more were deleted, assuming that patients did not use the exercise-based telerehabilitation service for 2 hours and forgot to log out. It is unknown whether this is the correct approach. Unfortunately, there was no secondary check (for instance use of a diary of patients) on the use date of chapter 5 and 6.

Conclusion

The thesis contributed to knowledge concerning the added value of telemedicine service for physical rehabilitation. Results show that telemedicine services have potential to comply with the increased demand of care in the field of rehabilitation and other fields. To provide concrete guidelines to other researchers active in the field of evaluation of telemedicine services the "DeChant" framework [4] is refined into a new staged approach framework focusing on four different aspects 1] evaluation objective, 2] evaluation context, 3] evaluation design and 4] evaluation endpoints. Actual use is an aspect that is hugely underexposed given that it is significantly related to clinical outcome and the measure that reflects real adoption of telemedicine by its end users. In addition, based on the knowledge that actual use of telemedicine decreases over time, it is important that new tools and techniques will be developed that improve actual use. It is hypothesized that this can be realized on one hand by enhancing technologies, such as using ambulant technology that allows objective monitoring and feedback and gaming technology but also by addressing implementation strategies such as implementation intentions.

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A black and white photograph of a weathered wooden surface. The wood shows signs of age, with numerous cracks, scratches, and areas where the surface material has chipped or peeled away. On the right side of the image, a metal fastener, possibly a bolt or screw head, is visible, partially obscured by the wood's texture. The lighting is dramatic, highlighting the rough textures and deep shadows within the cracks.

CHAPTER 9

*Summary, Samenvatting, Dankwoord,
Curriculum vitae, Progress range*



Summary

According to the Dutch Technical Appointment (NTA) telemedicine is defined as a process in (health) care, meeting at least the following two features; (1) distance is bridged by using Information and Communication Technology (ICT) and (2) there are at least two persons involved with at least one of them being a registered healthcare professional or acts on behalf of an registered healthcare professional. The first telemedicine services aimed to deliver healthcare to under-served areas. Whereas, nowadays, there is an imperative for telemedicine to be an answer to our increasing demand for care and increasing costs of health care. At the end of the 20th century telemedicine was introduced in rehabilitation; telerehabilitation. It is expected that telerehabilitation will increase accessibility, increase quality and lower costs related to rehabilitation. Despite this great potential, its implementation in daily clinical practice is very limited and most services fade away after a project or pilot phase. The aim of this thesis is to contribute to knowledge concerning the added value of telemedicine services for physical rehabilitation.

As part of this thesis, two state of the art evaluation studies of various telemedicine services for physical rehabilitation were performed. For these studies the stage approach for evaluation of telemedicine by Dechant et al., 1996 was applied. The first study (chapter 2) focused on the evaluation of the myofeedback-based teletreatment service for patients suffering from nonspecific neck and shoulder pain (stage 4). This service consisted of a garment with incorporated dry surface electrodes. The electrodes continuously record the upper trapezium muscle activation patterns. If there is insufficient muscle relaxation, the processing unit connected to the garment, vibrates and creates a soft sound. The processing unit is connected to a smartphone and the data from the unit are sent to a remotely accessible server. Results showed that there was a beneficial effect of myofeedback-based teletreatment service on both perceived pain intensity and disability in almost 40% of the patients. This service was clinically at least as effective as conventional care. Efficiency for therapists was increased by almost 20% and patients experienced the advantage of less travel time and travel costs by remote consultation.

The second study (chapter 3) involves an evaluation of a telemedicine service implemented as a partial replacement of a physical outpatient rehabilitation program for patients with chronic lower back pain (CLBP) or pulmonary disease (PD) (stage 3). This service makes use of a notebook with webcam and consists of two treatment modules. Module one contains a database of exercise videos. Module two, a teleconference service, facilitating contact between patient and the healthcare professional. With these modules, the professionals remotely compose an individual tailored exercise program and supervise the patient. The quality of care of the rehabilitation program for patients suffering from a chronic condition remains equal by replacing 1 day at the clinic with 1 day of home rehabilitation, by using an exercise-based tele-rehabilitation service. There was a beneficial effect of exercise-based tele-rehabilitation on pain intensity for 70% of the CLPB patients and on dyspnoea for 54% of the PD patients. Concerning the accessibility of care, patients were able to use the service during the outpatient rehabilitation program. Scores on satisfaction and usability were sufficient but slightly disappointing. Overall, the results show that telemedicine services have potential to comply with the increased demand of care in the field of rehabilitation and other fields.

In addition to the evaluation studies performed, chapter 4 of this thesis describes the results of a literature study that tried to answer the question whether the evaluation studies performed so far provide sufficient evidence to convince healthcare professionals, policy makers and insurance companies to implement telemedicine services into daily clinical practice. Chapter 4 presents an overview of telemedicine services for remote physical rehabilitation by analysing the technology that is used, the clinical purpose for which it is used as well as the way it is delivered to the patients (service configuration). Results showed that there is a large heterogeneity in these three characteristics of a telemedicine service which is largely neglected in previous performed reviews that tried to compile results of different studies. In addition, looking at the individual studies that focused on evaluation of telemedicine it becomes clear that the outcome parameters used are not tuned at all on the added value that might be expected from the service being researched or in other words and by this reason often not the right outcome parameters. Next to this, at this moment most telemedicine services are evaluated as standalone services. However to get insight into the impact of the telemedicine service on a health delivery system telemedicine services should be evaluated as being implemented in daily clinical practice. A conclusion of chapter 4 is that the expected added value should be defined a priori and should be used as starting point for choosing the outcomes. This added value should be defined taking into account the technology used, the clinical purpose the telemedicine service is used for and the service configuration. In order to provide concrete guidelines to other researchers active in the field of evaluation of telemedicine services the "DeChant" framework is refined into a new stage approach framework focusing on four different aspects 1] evaluation objective, 2] evaluation context, 3] evaluation design and 4] evaluation endpoints. This framework is presented in chapter 8, the general discussion.

A second aspect that is being researched in this thesis is the actual use of telemedicine services. Actual use is considered important as in face-to-face physical rehabilitation there is increasing evidence that intensive programs (high use levels) are more effective on health outcome than programs with a lower level of intensity (low use levels). Chapter 5 focuses on the actual use, clinical benefit and its mutual relationships concerning the myofeedback-based telerehabilitation service for chronic pain patients. The actual use of the service showed that participants used the service to a sufficient level i.e. the minimal hours that were prescribed. However, the actual use decreased during the four weeks of treatment period. Besides, there was a significant association between the total hours and clinical benefit in pain relief. The aim of chapter 6 was to examine the use pattern of the exercise-based telerehabilitation service by chronic patients and to examine the association between actual use and clinical benefit experienced by the chronic patients. Results show that the average use was 1-2 times a week in terms of frequency and a total of 35-38 minutes per week in terms of duration. This is less than what was replaced by the rehabilitation program at the rehabilitation center and even for this service the actual use decreased during the treatment period. Results also show that there was a significant association between the total frequency of use and clinical benefit in physical function meaning that those exercising more often gain more.

As such based on these results of Chapter 5 and 6 it is concluded that increasing the actual use of a telemedicine service for instance by implementing strategies is important. In addition there is an urge for new tools and techniques that improve actual use. One

suggestion is the use of gaming technology which is hypothesized to distract patients from their complaints, to make exercising fun, therefore increasing the compliance and actual use. A first explorative study on gaming technology is performed in chapter 7. In this chapter an exergame for physical rehabilitation of chronic pain patients was evaluated. The overall aim of the exergame is to improve the patient's physical condition. This exergame is controlled by relevant motions of the patient's body captured by a motion suit, several infrared cameras and by muscle activation levels. In three different integrated mini-games, the patient trained the following motor skills: walking velocity, overhead reaching and neck mobility. Given the results of this evaluation it was concluded that an exergame could be a promising tool for achieving physical rehabilitation because it motivates patients to perform their exercises. Next to exergames, gamification might offer a great potential to motivate end-users as well as pervasive technologies or making use of implementation intentions. These are discussed in more detail in chapter 8. From literature and experience it is known that despite patients and therapists having the intention to use the service they do not put these intentions into practice. By formulating very specific and detailed intentions, so-called implementation intentions, the intention-behavior gap can be bridged to enhance the likelihood that intentions are translated into behavior. Another suggestion are new tools and techniques relating to the field of pervasive health technologies. Examples of pervasive health technologies are ambulant technology that allows objective monitoring and feedback during everyday life activities or providing motivational messages based on a patient's compliance to exercises or progress being made.

Samenvatting

Telemedicines wordt volgens de Nederlandse Technische Afspraak (NTA) gedefinieerd als een proces in de gezondheidszorg dat tenminste voldoet aan de volgende twee criteria; (1) afstand is overbrugd door gebruik te maken van Informatie en Communicatie Technologie (ICT) en (2) er zijn tenminste twee personen bij betrokken en één van deze personen is een geregistreerd zorgverlener of treedt op namens deze geregistreerde zorgverlener. De eerste telemedicine diensten maakten het mogelijk om zorg te leveren in gebieden waar zorg niet of weinig voor handen was. Maar tegenwoordig wordt telemedicine gezien als de oplossing voor de groeiende zorgvraag en stijgende kosten van onze gezondheidszorg. Aan het einde van de twintigste eeuw is telemedicine geïntroduceerd in de revalidatie, oftewel telerevalidatie. De verwachting is dat telerevalidatie positief bijdraagt aan een betere toegankelijkheid en kwaliteit van de zorg en lagere zorgkosten. Ondanks deze verwachtingen is de implementatie van deze telerevalidatie diensten in de dagelijkse praktijk erg beperkt en de meeste diensten blijven op de plank liggen na een project of pilot fase. Het doel van dit proefschrift is om bij te dragen aan de kennis over de meerwaarde van telemedicine diensten voor de revalidatie.

Als onderdeel van dit proefschrift, zijn twee evaluatiestudies van twee verschillende telemedicine diensten voor de revalidatie uitgevoerd. Voor beide studies is gebruik gemaakt van "the stage approach to evaluation of telemedicine" van DeChant et al., 1996. De eerste studie (hoofdstuk 2) betreft een evaluatie van de op myofeedback gebaseerde telerevalidatie dienst voor patiënten met niet-specifieke nek en schouder klachten (stage 4). De dienst bestaat uit een vestje met droge oppervlakte elektrodes daarin verwerkt. Deze elektrodes monitoren continu het spieractivatiepatroon van de nek- en schouderpijnen (M.Trapezius). Wanneer er onvoldoende spierontspanning is, wordt er een trilsignaal en zacht geluid afgegeven door een kleine processor die verbonden is aan het vestje. Deze processor is tevens verbonden met een smarttelefoon die het mogelijk maakt spieractivatie data te versturen naar een op afstand toegankelijke server. Uit de resultaten blijkt dat het gebruik van deze telerevalidatie dienst een positief effect heeft op zowel de pijnintensiteit als de ervaren beperking bij 40% van de patiënten. Deze dienst is even effectief als reguliere zorg. Daarnaast was er een efficiëntie winst van 20% voor de therapeut en door de consultatie op afstand was er voor de patiënt minder reistijd en reiskosten. De tweede studie (hoofdstuk 3) betreft de evaluatie van de telemedicine dienst die als een gedeeltelijke vervanging van een regulier revalidatieprogramma voor patiënten met chronische lage rug klachten en luchtweg gerelateerde klachten is ingezet (stage 3). Deze dienst maakt gebruik van een laptop met webcam en twee behandelmodules. De eerste module bestaat uit een databank met bewegingsvideo's. De tweede module is een teleconsultatie dienst die het mogelijk maakt dat patiënt en therapeut op afstand contact met elkaar kunnen hebben. Door gebruik te maken van deze twee modules kan de therapeut op afstand voor een patiënt een op het individu afgestemd revalidatieprogramma samenstellen en deze patiënt op afstand begeleiden. Door één dag behandeling in de revalidatiekliniek te vervangen door één dag behandeling in de thuissituatie door gebruik te maken van deze telemedicine dienst, bleef de kwaliteit van het revalidatieprogramma voor deze chronische patiënt gelijk. Voor 70% van de chronisch lage rug pijn patiënten had het gebruik van de dienst een positief effect op de pijn intensiteit. Bij 54% van de patiënten met luchtweg gerelateerde klachten was er ook een positief effect op de kortademigheid door gebruik te maken van deze

dienst. Patiënten waren in staat gebruik te maken van de technologie. De uitkomsten op tevredenheid en gebruikersgemak waren voldoende, maar tegenvallend. Op basis van de resultaten uit deze beide studies wordt geconcludeerd dat telemedicine diensten een antwoord kunnen zijn op de groeiende zorgvraag in de revalidatie maar ook in ander medische disciplines.

Naast deze evaluatiestudies, beschrijft hoofdstuk 4 van dit proefschrift de resultaten van een literatuur studie. In deze studie is geprobeerd om een antwoord te vinden op de vraag of de huidige evaluatiestudies voldoende bewijs leveren om zorgprofessionals, beleidsmedewerkers en verzekeringsmaatschappijen te overtuigen om telemedicine diensten in te zetten in de dagelijkse praktijk van de zorg. Hoofdstuk 4 geeft een overzicht van de huidige telemedicine diensten voor de revalidatie, door een analyse op de technologie die wordt gebruikt, het klinisch doel dat wordt nagestreefd en de wijze waarop deze dienst wordt aangeboden aan de patiënten. Uit de resultaten komt naar voren dat er een grote mate van heterogeniteit is binnen deze drie karakteristieken van telemedicine diensten waar geen rekening mee wordt gehouden in eerder uitgevoerde reviews. Daarnaast blijkt uit de individuele evaluaties studies dat de uitkomstmaten van de meeste evaluatiestudies niet geschikt zijn omdat ze niet gerelateerd aan de meerwaarde die verwacht mag worden van de telemedicine dienst die wordt onderzocht. Daarnaast blijkt dat op dit moment worden de meeste telemedicine diensten geëvalueerd als op zichzelf staande diensten terwijl om inzicht te krijgen in het effect van telemedicine diensten op de zorg deze diensten als onderdeel van de dagelijkse zorgpraktijk geëvalueerd zouden moeten worden. Een conclusie van hoofdstuk 4 is dat een vooraf bepaalde meerwaarde van de telemedicine dienst het uitgangspunt moet zijn van een evaluatie. Deze meerwaarde is afhankelijk van de technologie die wordt gebruikt, het klinisch doel dat wordt nagestreefd en de wijze waarop deze dienst wordt aangeboden aan de patiënten.

Om handvatten aan te bieden aan andere onderzoekers op het gebied van het evalueren van telemedicine diensten wordt het raamwerk van "DeChant" verfijnd tot een nieuw raamwerk rekening houdend met 1] het onderzoeksdoel, 2] de onderzoek context, 3] de onderzoekopzet en 4] de uitkomstmaten van het onderzoek. Dit raamwerk is gepresenteerd in hoofdstuk 8, de algemene discussie.

Het daadwerkelijke gebruik van telemedicine diensten is het tweede onderdeel van dit proefschrift. Daadwerkelijk gebruik moet gezien worden als een belangrijke factor omdat in de revalidatie steeds meer bewijs voorhanden komt dat intensieve programma's (hoog niveau van gebruik) meer effectief zijn dan programma's met een lagere intensiteit (lagere niveau van gebruik). Hoofdstuk 5 richt zich op het daadwerkelijk gebruik, het klinische voordeel en de relatie tussen beiden voor de eerder beschreven op myofeedback gebaseerde telerevalidatie dienst voor chronische pijn patiënten. Uit de data blijkt dat op basis van een vooraf ingesteld minimum aantal uren de patiënten voldoende gebruik maken van deze dienst. Maar tijdens de behandel periode neemt het gebruik van de dienst af. Daarnaast is er inderdaad sprake van een significante relatie tussen het totale gebruik in uren en het klinische voordeel op pijnintensiteit. Het doel van hoofdstuk 6 is het gebruik van de eerder beschreven telemedicine dienst met twee modules (databank met bewegingsvideo's en teleconsultatie) en de relatie tussen daadwerkelijk gebruik en klinisch voordeel ervaren door de chronische patiënten in kaart

te brengen. Het gemiddelde gebruik van deze dienst was 1 tot 2 keer per week voor een periode van gemiddeld 35-38 minuten per week. Deze frequentie en duur verhouden zich niet tot de dag die vervangen is door gebruik te maken van de dienst en zijn als dusdanig teleurstellend. Ook hier wordt het daadwerkelijk gebruik minder gedurende de looptijd van de behandeling. Wederom was er wel een significante relatie tussen de totale frequentie van gebruik en het klinische voordeel in fysiek functioneren. Uit deze resultaten blijkt dat een toename van het daadwerkelijk gebruik van telemedicine diensten belangrijk is en nieuwe strategieën en technieken ontwikkelen moeten worden die dit daadwerkelijk gebruik verbeteren. Een mogelijke oplossing is de inzet van gaming technologie. Deze technologie heeft als mogelijke voordelen: het afleiden van de patiënt van zijn klachten, bewegen leuk en uitdagend te maken en hierdoor de therapietrouw en het daadwerkelijk gebruik te verbeteren. Een eerste studie naar de mogelijkheden van gaming technologie staat beschreven in hoofdstuk 7. In dit hoofdstuk is een bewegingspel voor de revalidatie van chronische pijn patiënten onderzocht. Het algemene doel van dit beweegspel is de fysieke conditie van de patiënt te verbeteren. Het beweegspel wordt aangestuurd door relevante bewegingen van de patiënt. Deze bewegingen worden geobjectiveerd door gebruik te maken van een pak met markers, verschillende infrarood camera's en het spieractivatiepatroon van de patiënt. In drie verschillende geïntegreerde spelletjes kan de patiënt de volgende vaardigheden trainen: loopsnelheid, reiken boven het hoofd en de mobiliteit van de nek. Gegeven de resultaten van deze evaluatie kan geconcludeerd worden dat een bewegingspel een veelbelovende technologie kan zijn voor de revalidatie, omdat het de patiënten motiveert om hun oefeningen uit te voeren. Naast deze gaming technologie biedt ook gamificatie, mogelijkheden om patiënten te motiveren. Andere mogelijkheden om het daadwerkelijk gebruik te verhogen, beschreven in hoofdstuk 8, zijn "pervasive technologies" en het gebruik van implementatie intenties. Uit de literatuur en ervaring blijkt dat terwijl patiënten en therapeuten de intentie hebben om gebruik te maken van de telemedicine dienst, dit niet altijd leidt tot daadwerkelijk gebruik. Door het formuleren van specifieke en gedetailleerde intenties (implementatie intenties) kan de kloof tussen intentie en gedrag worden gedicht. Intenties worden nu vertaald in daadwerkelijk gedrag. Een andere oplossing is gebruik te maken van nieuwe technieken voortkomend uit het onderzoek domein van de "pervasive healthcare". Voorbeelden zijn draagbare technologieën die het mogelijk maken om objectief te monitoren en feedback te geven tijdens algemene dagelijkse activiteiten of technologieën die motiverende berichten kunnen versturen aan de patiënt op basis van zijn therapietrouw of voortgang.

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“Give every day the chance to become the most beautiful day of your life.” (Mark Twain)

Curriculum vitae

Stephanie Jansen – Kosterink was born in Hengelo (ov), the Netherlands on the 2nd of November, 1982. In 2001 she started her education in Human Movement Science at the VU University in Amsterdam. After the two years of a general introduction to the Human Movement Science she focused on the main subject “Human Movement Science in the context of Healthcare”, specialization psychomotor therapy (PMT). In her fifth and final year she followed an internship at KARAKTER in Ede, an institution for children and young adults with a mental disorder. She worked there as a PMT-therapist. In the final year she also followed a teacher training program. She graduated in 2006.

After her graduation she was appointed as a teacher (Science, Biology) on a secondary school, Sg. St. Canisius in Almelo. In October 2008, she joined Roessingh Research and Development (RRD), in Enschede, as a research assistant on the MoyTel project. After this project she continued working for RRD as PhD researcher in the field of Telemedicine. She worked on a number of European and National projects, including MyoTel (eTEN), CLEAR (ICT-PSP), PLAYMANCER (FP7-ICT) , Condition Coach (NL Agency), NavMem (AAL) and PERSSILAA (FP7-ICT). In these projects she was engaged with the assessment and validation of the clinical trial. Currently, Stephanie is employed as a post-doctoral researcher at Roessingh Research and Development.

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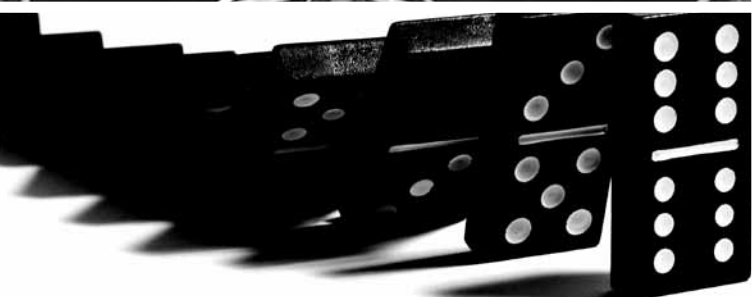
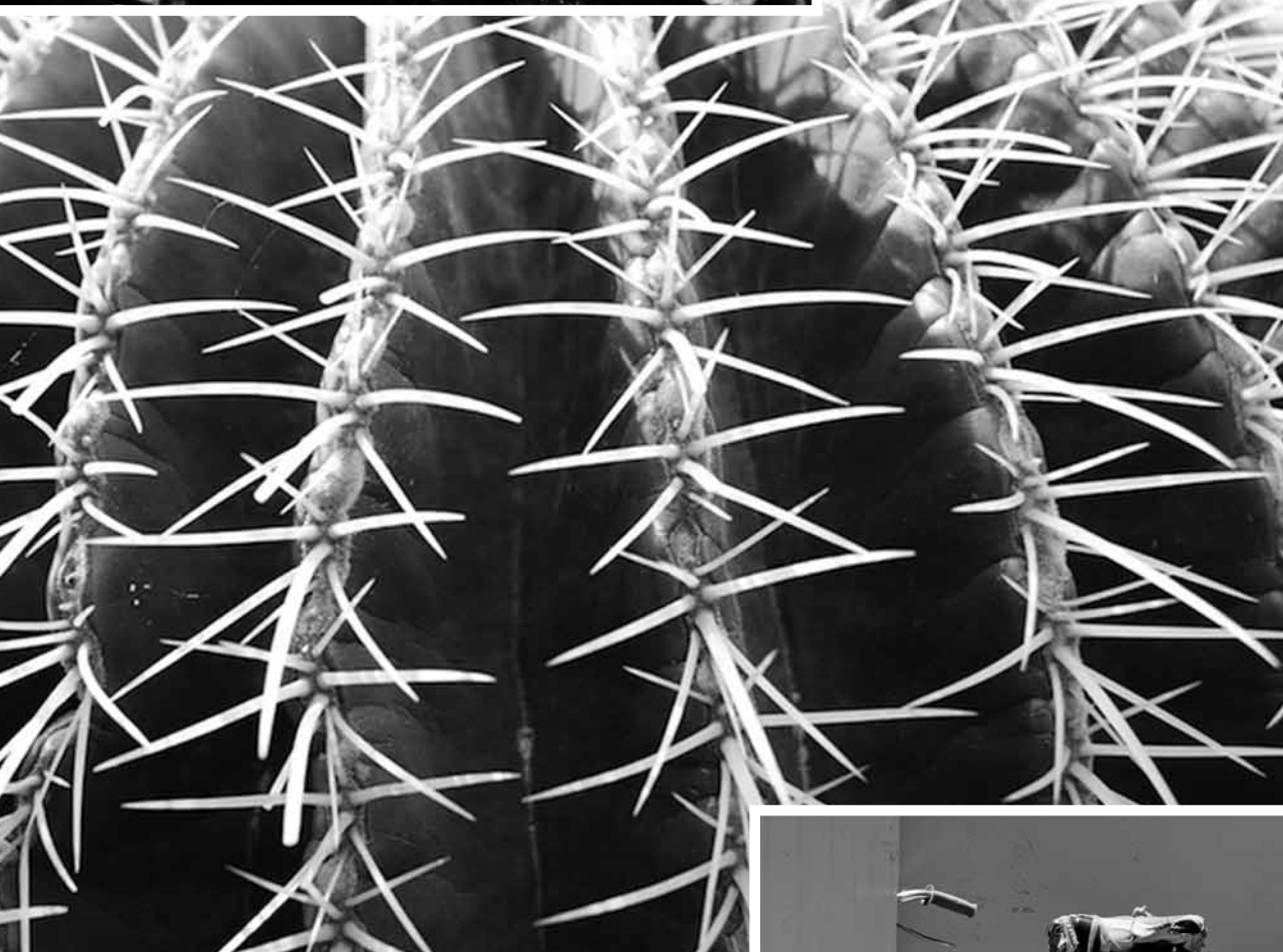
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