Serious Games for Stroke Patients: Attending to Clinical Staff's Voices

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Abstract: A motion-based rehabilitation game is gaining a solid ground in that it can provide the stroke patients with the repetitive training effect for a functional improvement of upper extremity (UE). Many proved potential utilities of the motion-based rehabilitation games for the first stakeholders, i.e., patients, but the organizational benefits for other key stakeholders (e.g., clinical staff such as physiatrists and occupational therapists) have been less attended. This paper reports on our design experience of a natural interaction based rehabilitation program – '*RehabMaster*', addressing the rather different requirements from the clinical staffs. A practical rehabilitation session assessed a two-week clinical trial with sixteen stroke patients, seven physiatrists and three occupational therapists, and essential requirements of the clinical staffs were observed. We learnt that a key to the clinical-level serious game design is to mimic actual social settings of what the stakeholders are indeed interacting with.

Key words: clinical staff, stroke, motion-based rehabilitation game, contextual inquiry

1. Introduction

Stroke leads one of the primary causes of long-term disability among senior adults in many developed countries, and around 80% of the stroke survivors reserve significant motor skill impairments [17,19], including upper extremity (UE) functional deficits. In the last decade (2002-2012), for instance, about 1.6 million patients have been hospitalized in Korea, and the number of stroke inpatients has been incessantly increasing at a compound annual growth rate of 6.4% [16].

Evidence shows that the effectiveness of the rehabilitation training program depends upon both intensity and frequency of the program [17], and a simple and uniform repetitive training was not successful in this respect, especially in the home-based stroke rehabilitation program. Many studies thus questioned how to work out the motivational power (or at the very least, the will-power to last the exercises) of the stroke patients for a long-term rehabilitation process [2,3,6,11]. Here, an important contribution of the HCI (Human-Computer Interaction) studies can rest on how to design the rehabilitation program.

Though the game-based rehabilitation systems (e.g., Nintendo Wii Fit™ or Microsoft Xbox Your Shape™ Fitness Evolve) have been highly welcomed in this respect, they seem controversial on the clinical staff's view while employing at the clinical setting [13,14,20]. This is partly because of no strong validation of the clinical effects and mostly because the medical staffs are still reluctant to insert the off-the-shelf games into their conventional rehabilitation program. Indeed, in the clinical rehabilitation session, stroke patients should interact with either physiatrists or occupational therapists and these interactions remain as the core part of successful rehabilitation. However, few motion-based rehabilitation programs have considered the interactions between the stroke patient and the clinical staff, and the usefulness of serious games (except pleasant to use) is not appealing to the current clinical practices of what both the physiatrist and the occupational therapist are doing.

The aims of the project are thus two-fold: 1) to design a motion-based rehabilitation game called *RehabMaster*, not only for the stroke patient, but also simulating the occupational training (OT) session of the clinical staffs; and 2) to validate its clinical advantages and its usability in terms of three stakeholder's stances (i.e., stroke patients, physiatrists, and occupational therapists).

In the following sections, we applied a simplified HCI design process consisting of the three sessions: (1) understanding a clinical setting; (2) extracting usability factors for different stakeholders; (3) designing a motion-based rehabilitation system. Section 3 describes an experimental test of the system *RehabMaster* at a clinical setting and the quantitative and qualitative results of the empirical study are then interpreted. Finally, Section 4 provides lessons learnt about an overarching perspective including both stroke patients and clinical staffs, and the potential contributions of serious games in the rehabilitation program are further discussed.

2. A Design Study: RehabMaster™

2.1 Understanding a clinical setting

In order to understand how the rehabilitation process for stoke patients works out, the contextual inquiry methods were employed, including on-site focus group interviews, on-site individual interviews, and on-site video-recording observation at a clinical setting. We first held focus group interviews, in order to understand how the rehabilitation process for stoke patients is managed in practice. Four stakeholders (i.e., stroke patients, their caregivers, physiatrists and occupational therapists) were then interviewed at a clinical setting for two weeks. We also carried out a one-week observation session of how the stakeholders are interacting one after another. Below is an example of the interaction between the stroke patient, Bob (changed for anonymity), the physiatrist and the occupational therapist at the clinic.

Bob (changed for anonymity) was diagnosed as upper extremity (UE) functional deficit after stroke. After being recovered from the operation to some extent, Bob visited to a rehabilitation clinic. The physiatrist tested Bob's upper limb motor function and prescribed an occupational therapy program best appropriate for Bob's symptom. With this prescription, Bob had a training session every two days with the therapist at the clinic. At first, Bob hardly moved his right arm. So, the therapist often paused training until Bob completed a particular movement. Sometimes Bob's condition was good, so he could move wide and fast. However, it could be taken a sudden turn for the worse, so someday he could not merely move his arm up and down. To reflect this rapid condition change problem, the therapist modified the level of prescriptive training program. After a two-week training session, Bob visited the physiatrist again. She checked the progress report and prescribed new occupational therapy for the next exercise.

As above, clinical staffs closely interact with the patient to ask for him to perform a best rehabilitation program (Figure 1). A critical requisite for success rests on the information of how he was treated and progressed along with his prescribed exercise program. However, we found that most of off-the-shelf serious games (e.g., Nintendo and Xbox game titles) for stroke patients are not available for clinical staffs to obtain such critical information. Of particular interest here was a lack of proper information acquisition system from the games, and consequently the physiatrist cannot prescribe a best possible rehabilitation treatment for different symptoms. Further, as a perpetual contact point for the rehabilitation program, occupational therapists are not able to fully control the off-the-shelf serious games for developing customized exercises. For instance, we found that as the patient complains of severe pains while exercising, the occupational therapists should have some authority to control the rehabilitation program.

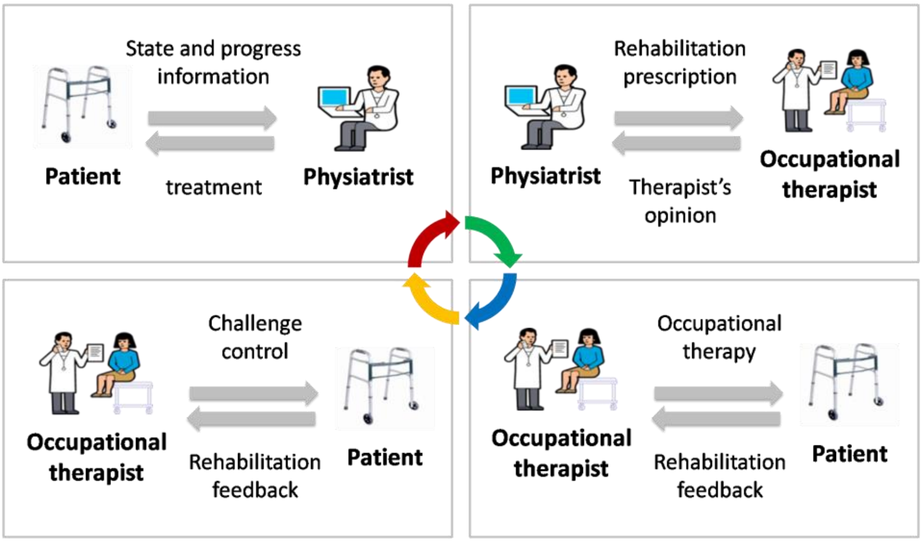


Figure.1 Interaction between stroke patients, physiatrists and occupational therapists at the clinical setting

2.2 Extracting usability factors for different stakeholders

Next, we developed a core set of usability factors for each stakeholder, as shown in Table 1. It illustrates relevant design factors and potential effects for each user group in the actual clinical setting, which retrieved from our focus group studies and previous literature [2-4,6,8,9,11]. Firstly, many studies on the home-based rehabilitation game have emphasized the importance of „meaningful play" and „challenge" of the stroke patents. Meaningful play emerges from a game through the relationship between a player's actions and the outcomes that are closely related to the purposes of rehabilitation. This, of course, leads the stroke patients to increase motivation and enjoyment [6,9]. Challenge is also important because it affects a player's on-going enjoyment and engagement on the horizon of experience [6]. For instance, if challenges are too high for the player, he or she becomes easily frustrated and quitting would be a result [10].

As to the physiatrists, they asked to easily obtain reliable information about a patient's state as well as progress from the serious games. In particular, they wanted to have an occupational prescription module that can easily manage meaningful serious games for UE rehabilitation. In contrast, occupational therapists, concerning their current work practices, tend to meet more than one patient at a time. Normally, they deal with three or four patients at the same time. Due to the massive and frequent uses of serious games, the occupational therapists asked it to be easily configurable. For instance, they mentioned that an appropriate level of therapy needs to be easily set or improvised while playing, depending on the current state and the prospect of the patients.

Table 1. Usability factors for different stakeholders. Its potential outcomes are also identified by both interviews and literature review

User group	Usability factor	Proposed outcomes
Stroke patients	Meaningful play	Increased motivation and enjoyment [6,9]
	Challenge	Continuous enjoyment [6,9]
Physiatrists	Information acquisition	Get the information of patient's progress [4,9]
	Meaningful prescription	Proper prescription for patient's symptom [4,6,9]
Occupational therapists	Easy to use	Easy to configure and start a serious game [4,8]
	Challenge	Easy to control challenge while playing [4,6,8,9]

2.3 Designing a motion-based rehabilitation system

Based on the above rather different user requirements, we tailored a high-fidelity prototype with a motion-based serious game, called *RehabMaster*. Its rehabilitation training simulates arm movements to restore specific functional deficits as shown in Figure 2, in which the patients attempt to be able to mimic the motions pre-recorded for perfect limb movements.

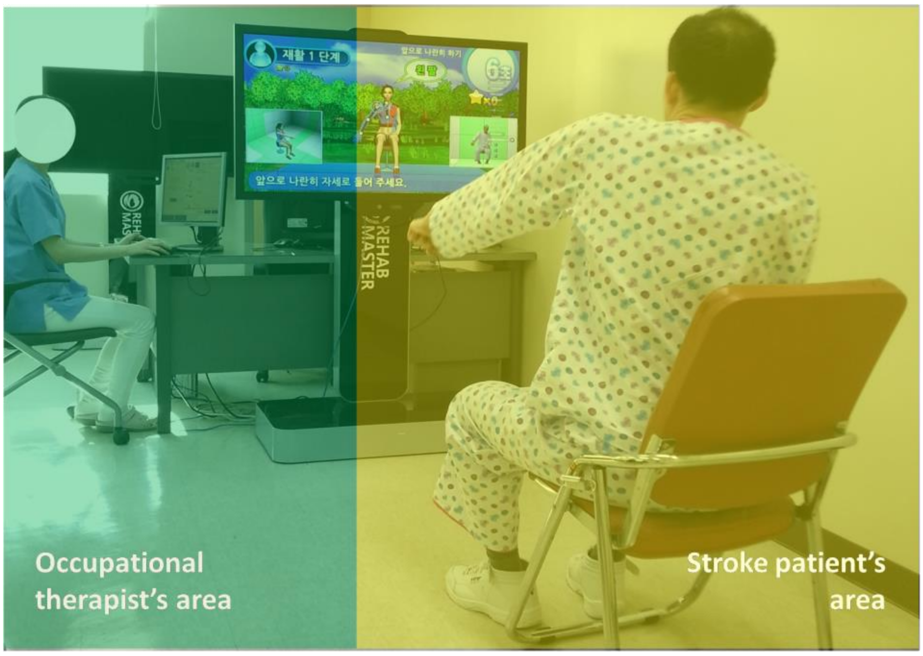


Figure.2 RehabMaster: Upper extremity (UE) rehabilitation training

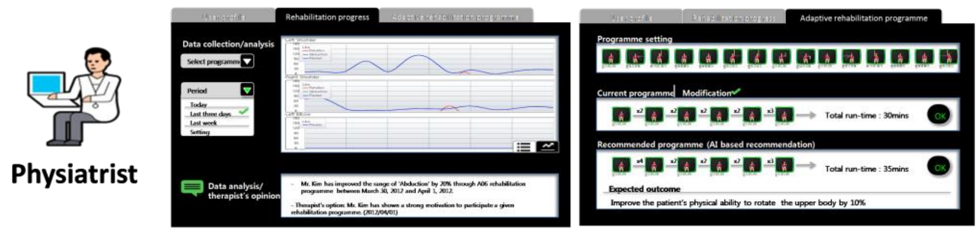
At a practical setting the occupational therapists can manage 40 different training exercises which are based on the motion of Fugl-Meyer Assessment (FMA) at the different levels of difficulty [12]. While a stroke patient plays with RehabMaster, the occupational therapist also provides physical assistance, verbal feedback, and emotional encouragement. This clinical trial generally takes a whole two-week period, around once a day for 20 minutes. All the training data are transferred into the main database, and the physiatrist is able to use these data to diagnose as well as further prescribe the customized exercise treatment.

Based on our usability factors (See Table 1), the *RehabMaster* is aimed at not only the stroke patient, but also the clinical staff for their actual working environment, so we need to develop the three different types of user interfaces (UIs): physiatrist's UI, occupational therapist's UI and patient's UI.

Firstly, the interface for the physiatrist consists of two key elements: the user management UI that contains information of the stroke patients (i.e., a detailed medical record of the stroke patients, history of the practices with *RehabMaster* and note-taking recorded by occupational therapists); the prescription UI that helps the physiatrist to coordinate meaningful rehabilitation trainings or suggest some serious games relevant (See Figure 3a).

Secondly, the occupational therapist's interface consists of four: the user management UI that is exactly the same with the physiatrist's UI; the assessment UI that evaluates the rehabilitation progress; the editable UI for rehabilitation training that can assign personalized limb training exercises (Figure 3b-left); and the rehabilitation games editing UI that allows them to manage a series of best games for the current state of the stroke patient (Figure 3b-right). All these occupational therapist's UIs are easy to configure (e.g., pause, start and stop) and control challenging levels while using at the clinical setting.

Thirdly, the UI for the stroke patient relies on the assessment of their limb movements, and the calculated scores against the perfect limb movement are presented on the display like Figure 3c.



(a) Physiatrists: User management UI (left) and prescription UI (right)

(b) Occupational therapists: Editable UI for rehabilitation training (left) and rehabilitation game editing UI (right)

(c) Patients: Rehabilitation training (left) and rehabilitation game (right)

Figure.3 Three different user interfaces in the '*RehabMaster*'

3. A clinical study in an actual setting

One of main objectives of the project was to see whether the consideration of the three different kinds of user interface (UI) would serve to ensure the uptake of *RehabMaster* in an actual clinical setting. Usability tests with the three user groups (i.e., physiatrists, occupational therapists and stroke patients) are necessitated. In so doing, *RehabMaster* was installed in a rehabilitation hospital for two weeks, and a clinical test and a usability test were blindly performed. Total seven physiatrists and three occupational therapists employed *RehabMaster* for their actual work practices. All of them had never used any motion-based rehabilitation program and they were trained to use *RehabMaster* for two hours before the usability test.

3.1 Part1: Clinical test

Firstly, the clinical test was performed with sixteen 'acute-to-subacute' stroke patients (7 acute and 9 subacute/ 8 males and 8 females/ age M = 49.6, SD = 10.1). All the participants have suffered hemiparetic upper limb dysfunction secondary to first-ever strokes. They provided written informed consent and this study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the author's institute. Total seven physiatrists and three occupational therapists employed the *RehabMaster* for their actual work practices.

Stroke patients were randomly assigned into two groups (OT only group: a conventional occupational therapy (OT) for 20 minutes; *RehabMaster*+OT group: 10 minutes *RehabMaster* training plus 10 minutes conventional OT). Each group was assigned for ten sessions over two weeks. All sessions were administered by the trained occupational therapists who were blinded to the protocol. Baseline of two groups was compared using a Mann-Whitney U test before the main experiment, to verify the homogeneity of the participants. Then, Fugl-Meyer Assessment (FMA) for upper limb motor function (0 = lowest score; 66 = highest score) [12], and the Modified Barthel Index (MBI) (0 = lowest score; 100 = highest score) for global function evaluation [21] were used in the baseline (T0), the fifth session (T5) and the last session (T10). We conducted univariate analyses using Mann-Whitney tests to compare the FMA and MBI score changes between the „OT only‟ group and the „*RehabMaster*+OT‟ group. All analyses were performed using SPSS statistical software and statistical significance level refers to a $p \leq .05$.

3.2 Part 2: Usability tests

The patients and clinical staffs rated usability statements just after using *RehabMaster* for two weeks. The statements included separate concerns of each user groups. For instance, the patients assessed *RehabMaster* if it was able to make them immerse to the rehabilitation procedure. The physiatrists rated *RehabMaster* in a rather different viewpoint, such as it would be helpful to acquire patients‟ information or whether it was meaningful to prescribe exercises for the stroke patients. The occupational therapists also evaluated usability differently, such as whether *RehabMaster* was designed to easy to control while rehabilitation or whether it was flexible to control the challenge levels depending on the patient's state.

3.3 Results and Discussion

3.3.1 Part 1: Clinical test

Table 2 shows that there were no significant differences in the baseline characteristics between two groups, which are considered as a homogeneous group at the baseline (T0). After the ten sessions for two weeks, the upper limb motor function improvement of the participants was measured by Fugl-Meyer Assessment (FMA) as well as Modified Barthel Index (MBI).

Table 2. Baseline characteristics

Outcome	Age (s.d)	Days after onset (s.d)	FMA (s.d)	MBI (s.d)
OT only (n=7)	46.6 (5.8)	76.6 (28.5)	34.4 (12.4)	44.7 (9.1)
RehabMaster+OT (n=9)	52.0 (11.9)	67.1 (45.3)	39.4 (10.7)	59.9 (17.6)
p-value	*0.5*	*0.3*	*0.5*	*0.1*

In Table 3, the Fugl-Meyer Assessment (FMA) result shows significant (p =.07) improvement observed in the *RehabMaster*+OT group than in the OT-only group. Improvement in Modified Barthel Index (MBI) (p =.16) was greater in the *RehabMaster*+OT group (11.6±6.5) than in the OT-only group (7.7±4.6). Considering these results, serious games and motion-based rehabilitation programs presented by our *RehabMaster* could contribute to patient's upper limb motor function improvement.

Table 3. FMA and K-MBI results

Outcome	OT only (n=7)		*RehabMaster*+OT (n=9)	
	Pre	Post	Pre	Post
FMA	34.4 (12.4)	40.7 (9.8)	39.4 (10.7)	51.1 (17.8)
K-MBI	44.7 (9.1)	51.0 (8.8)	59.9 (17.6)	71.2 (15.4)

3.3.2 Part 2: Usability tests

Seven physiatrists assessed *RehabMaster* on two factors: information acquisition and meaningful prescription, as shown in Table 4.

Table 4. Usability ratings by physiatrists

Statements	**Mean (s.d)***
1. *RehabMaster* was able to provide relevant information of how a patient has been improved or not.	4.6 (0.5)
2. *RehabMaster* was effective to administer occupational therapy.	4.3 (0.8)
3. *RehabMaster* was able to design the whole rehabilitation process customizable for a particular patient.	4.7 (0.5)

**All the p-value for the two-tailed test was less than 0.01.*

It can be seen that most of the physiatrists were able to acquire proper information about the patients through the *RehabMaster* (mean 4.6 for statement 1). It also helped the physiatrist to manage diverse occupational therapies (4.3 for statement 2) and this could be customized for each patient, so they saw each therapy was meaningful for the different levels of patients (4.7 for statement 3). Three occupational therapists were also asked to rate the following two statements: "I was easily able to manage the therapy prescription with *RehabMaster*" and "I was able to improvise the rehabilitation program with *RehabMaster* depending on the actual performance of each patient." All the occupational therapists had strongly agreed with both statements, but no further analyses made due to the ceiling effect.

Table 5. Usability ratings by stroke patients

Statements	Mean (s.d)*
1. When using *RehabMaster* I was thought about other things.	1.3 (0.6)
2. *RehabMaster* was fun for me to use.	4.5 (1.1)
3. I felt that I had no control over my training process with *RehabMaster*.	1.3 (0.6)
4. When using *RehabMaster* I was frustrated with what I was doing.	1.9 (1.1)

**All the p-value for the two-tailed test was less than 0.01.*

Table 5 gives the mean ratings, across the four main contributors (attention focus, pleasant to use, meaningful play and challenge to motivation). All the patients mentioned that *RehabMaster* made them highly attentional focus on rehabilitation procedure (mean 1.3 for Statement 1). They also enjoyed the rehabilitation program (4.5 for Statement 2) and they took *RehabMaster* as meaningful (1.3 for Statement 3) as well as accordingly challenging (1.9 for Statement 4). As a whole, the sixteen patients liked to recommend *RehabMaster* to other patients. One-sample t-tests against the neutral value (3.0) supported the interpretations above.

Taken together, *RehabMaster* might be said that it can achieve satisfaction from all the relevant rehabilitation stakeholders and could be easily employed in a clinical rehabilitation setting. Design factors for each individual rehabilitation stakeholder and different user interface (UI) forms make it possible to encourage all user groups (physiatrists, occupational therapists and stroke patients) to actively see the benefits of serious game-based rehabilitation. In particular, the physiatrists who are considered as the main hurdle of adopting the motion-based rehabilitation also showed that the way it is asked to would be the key to accept the new interactive systems replacing their current work practices.

4. Lessons learnt and future work

The clinical and usability tests above demonstrated the usefulness of *RehabMaster* in an actual clinical setting, which has not been widely experimented in the HCI and design communities. In particular, an application of the user interface (UI) design process (e.g., focus group studies and interview, usability testing) in the medical field would be a practical contribution. From these we can draw out three lessons learnt that can inform a methodological and practical suggestion to designing a clinic-level serious game as follows:

- **Use of a high-fidelity prototype in the early design process**

It is commonly agreed that an early use of a high-fidelity prototype may place a restriction on the early design ideation. However, our experience with clinical staffs suggests that the high-fidelity prototype may need to help our stakeholders (e.g., stroke patients, physiatrists, occupational therapists) more vividly express their usability issues relative to imaginative game-based rehabilitation system at the clinical setting. This approach could be particularly combined with a series of contextual inquiry sessions. In line with our findings, the issue identified for example by Acuna and Sosa (2010) in the field of product design, supports that a concrete prototype can be more suitable than a low fidelity prototype to provoke a functionality aspect of creativity [1]. Whilst the use of high-fidelity prototype was mostly positive in our particular experiment, we also assume a negative impact, such as time-consuming, costly, and difficult works for in-house designers and HCI researchers, which can be problematic in some cases.

- **Effective and efficient information design by handing a large amount of patient data recorded**

From a physiatrist and occupational therapist perspective, one of the most important benefits of integrating a motion-based rehabilitation system instead of using a conventional occupational therapy (OT) alone is the fact that the system is capable of recording the upper limb motor function of the individual patient spontaneously. Large amounts of patient data (e.g., training time, performance, and game score) can be recorded for a short- and/or long-term so that progress in stroke recovery can be objectively measured, which is often hard to perceive in the current clinical environment [3]. In handing these big medical records, an information design issue can be raised here: "how can a patient progress be effectively and efficiently informed to patient itself and clinical staffs?" Apparently, the patient and clinical staffs have different concerns of their rehabilitation treatment as described in Table 1. For example, in our case study the physiatrists preferred to examine a patient progress chart on a weekly or a monthly basis to a daily. The potential for an effective way of information design creates interesting design challenges that need a further study.

- **Ease of customizing a system to maintain a suitable degree of challenge for an individual patient undergoing stroke therapy**

Finally, at a clinical setting, the most persistent requests from the physiatrist and occupational therapist are that the clinic-level serious game must provide the customizable rehabilitation program to maintain an appropriate level of challenges for a different degree of the stroke symptom. These might include a speed of movement, movement ranges, the number of sets and repetitions. One possibility could be that the physiatrist and occupational therapist can set a personalized goal based on the patient's progress, that they can effectively maintain the patient's motivation [3,6]. Most important, the clinical staffs need to control and prevent unexpected physical problems of the patient, which is an essential part of the clinical treatment. For example, in our case study, while one stroke patient played *RehabMaster* with his occupational therapist, he suddenly complained of severe pain in his left arm. Occupational therapists directly modified the rehabilitation program to use the right arm only and then added a supplemental rehabilitation program dedicated to his left arm at a low level challenge.

Through our design case study, we could find the design factors of a motion-based serious game dedicated to the stroke rehabilitation at a clinical setting and addressed many requirements of physiatrists, occupational therapist, and stroke patients. Another HCI design process will be again carried out by using the current version of *RehabMaster* as a provocative prototype (provotype), for instance [7]. This would be able to suggest other design factors that we have not considered in this article.

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