CHI: U: Autonomy-based Rehabilitation Design: Balancing Capability and Complexity

Kyoungwon Seo
Research Institute for Serious Entertainment
Hanyang University, Korea
cseo@hanyang.ac.kr

ABSTRACT
Autonomy, a state of being independent or self-governing, is critical to harness patient empowerment to in-home therapy programme, after being discharged from the hospital. How we support patient autonomy in an unsupervised home-based rehabilitation programme is arguably present in every healthcare system design decision and yet many questions surrounding autonomy-based design in healthcare systems and devices remain unanswered. In this context, the aim of this study is to share our experiences of designing the home-based rehabilitation platform for post-stroke patients, RehabMaster™, in particular for what kinds of autonomy supports should be of value for the in-home rehabilitation. Usefulness of the autonomy-based rehabilitation design was studied by a two-week home-based rehabilitation session with sixteen post-stroke patients and further design issues for autonomy were discussed.

PROBLEM AND MOTIVATION
Rehabilitating post-stroke patients needs an ongoing treatment for a long time, and in particular, motivating them to perseveringly engage into the treatment is key to success [5]. For a general treatment, as the hospitalization period (N.B. the state-covering insurance in Korea accepts only 8 weeks hospitalization for post-stroke patients) finished, most of the inpatients get back to their homes and are prescribed with a home exercise therapy programme. However, their recovery is much slower than their hospitalization period. One of the primary reasons for such deterioration is their weakened determination (or will-power) compared to the compulsory exercise programme in the hospitalization period [4]. Autonomy, the intention to act on the basis of one's own self-motivation, desires, and goals, is thus an important factor for a successful rehabilitation outcome for patients [7, 8].

To address these problems (e.g., the effect – outpatient's deterioration in health; the cause – weakened will-power at home), Hanyang University Medical School and Department of Industrial Engineering developed an autonomy-support rehabilitation platform, called RehabMaster™ (see Figure 1) under the umbrella project called the 'Ubiquitous Health Korea'. In this platform design, we applied Nessier's "*Perceptual Cycle Model (PCM)*" [11], in order to foster outpatients' autonomy in performing the home exercise therapy. According to PCM, well-designed feedforward is an effective tool for bridging the gulf between the user's intention (e.g., outpatient's intention to rehabilitate) and the execution (e.g., outpatient's action to rehabilitate) by helping her or him decide what action to be taken with the anticipated outcomes [17]. Throughout this paper, presented are both the autonomy-enhancing design for the outpatients and design issues which might be applicable to other related healthcare product design.

Figure 1: Autonomy-support rehabilitation platform – RehabMaster™ (left: apparatus, right: in-home installation)

BACKGROUND AND RELATEDWORK

Autonomy Levels in a Clinical Setting vs. Home-based Rehabilitation
In developing the rehabilitation platform – RehabMaster™, several contextual inquiry sessions were made for understanding how the rehabilitation process in Korea works [15]. The four types of stakeholders in the rehabilitation process (i.e., patients, caregivers, physiatrists, and occupational therapists) were in-depth interviewed at two clinics. A one-week full observation session was also carried out for understanding the interactions among the stakeholders.

In brief, at the clinic-based rehabilitation setting, the post-stroke patients actively interact with the physiatrist and occupational therapist twice a day. The physiatrist tests the post-stroke patient's limb functions and prescribes an appropriate exercise therapy programme that is best suited for the inpatient's status and progress. With this prescription, the occupational therapist 'verbally' or 'physically' motivates the post-stroke patient. Thanks to these externally motivated interactions between the inpatient and the clinical staffs (see Figure 2), less autonomy is required at a clinical setting.

Figure 2: Interactions between the inpatient and the clinical staffs (left, middle: verbal support, right: physical support).

However, we found that when the post-stroke patients get back to home, the externally motivating stimuli from the medical staffs mostly disappear [10]. Worse, at home, outpatients have to administer their in-home therapy programme by themselves. It might be said how to activate the outpatient's autonomy at home is crucial for a successful in-home rehabilitation therapy programme.

Autonomy-based Rehabilitation Design

Design to support outpatient's autonomy at home is also a challenge for Human-Computer Interaction (HCI) community which has close reliance to the issues such as rehabilitation design for motivation and behavior change [1, 3, 4, 15]. Issues of autonomy are heavily linked to one's motivation, user experience (UX) and even psychological wellbeing, but many questions surrounding design for autonomy remain unanswered as yet [4]. Recent HCI researches have thus emphasized the importance of *meaningful play* and *challenge* to support outpatient's autonomy at home [1, 3].

According to Balaam et al.'s study [1], meaningful play emerges from the relationship between an outpatient's actions and the outcomes that are closely related to the goals of rehabilitation. This guarantees the outpatients to have self-motivation at home. For this, an adequate level of challenge is thus important because it affects an outpatient's on-going enjoyment and engagement [3]. For example, if challenges are too high for the outpatient, he or she becomes easily frustrated and quitting the exercise would be a result.

Not only *meaningfulness* and *challenge level* of the home-based rehabilitation system, but also the features of interactive systems that promote a user's sense of autonomy are drawn attention from the researchers [2, 4-8]. Of our interest, several design factors for autonomy were then identified: 1) *System capability* (technological capability to realize user's goals); 2) *System complexity* (mismatch between user's abilities and system); 3) *Knowledge about the system* (explanations for helping users to understand system), and 4) *Misrepresentation of the system* (false or inaccurate information about the system) [7].

Though the design factors for supporting autonomy seem fair, how to deliver this quality is still elusive. In fact, in designing RehabMaster™, a pilot study with three post-stroke patients revealed that a generic usage of the design factors for autonomy are not enough to enhance their autonomy. For instance, post-stroke patients felt that self-choice of the rehabilitation exercises is a burden rather than an autonomy-enhancing design factor. The major reason for this undermined autonomy arises from the coupled design features – system capability and complexity. That is, a greater system capability is coupled with a greater system complexity in the use of the system [7; i.e., flexibility-usability tradeoff effect]. This means when many choices are given to patients (or caregivers at home), the complexity of self-determination is accordingly increased. This further suggests that self-determination among many choices is seen as cognitive burden rather than autonomy-support design. In this regard, we studied how to meet the system complexity for their self-determination.

UNIQUENESS OF THE APPROACH

Perceptual Cycle Model and Feedforward

To enhance post-stroke patient's autonomy at home, by balancing capability and complexity, we pay attention to Nessier's "*Perceptual Cycle Model (PCM)*" [11] as a conceptual approach to design a rehabilitation platform that might limit system capability for system complexity.

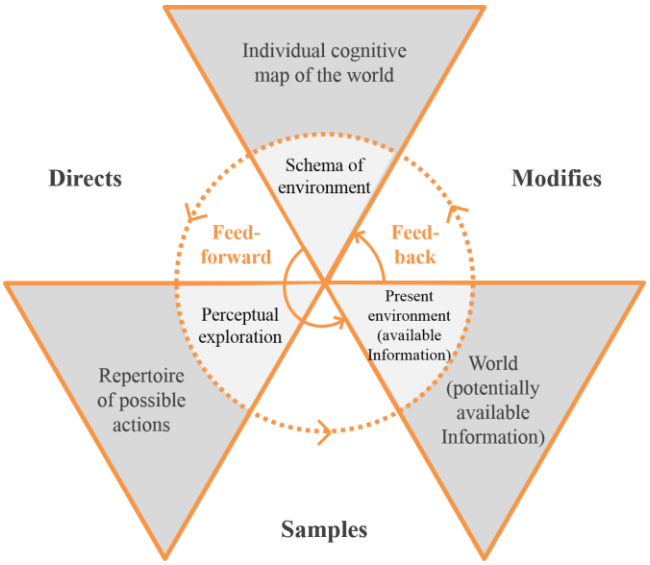

Figure 3: The Perceptual Cycle Model (PCM) [11].

PCM is a model that refers to the idea of a reciprocal and cyclical relationship between a person (e.g., post-stroke patients) and the world (e.g., in-home rehabilitation environment) as in Figure 3. According to this model, people seek out related information and develop world knowledge (schema) with this information (feedback in Figure 3). This schema then helps people to anticipate about certain information (feedforward in Figure 3). In PCM, this feedforward can help people (i.e., post-stroke patients) to expect certain outcomes (i.e., choosing a particular home

therapy that they can expect what kinds of outcomes would make). We hypothesized that our rehabilitation platform – RehabMaster™ – can successfully increase the outpatient autonomy level, by recommending a best-suited home therapy with expected results (i.e., feedforward).

Clinical Test and Usability Test

To verify the effect of feedforward (i.e., whether it can successfully stop the outpatient's deterioration and improve rehabilitation outcomes), both a clinical test and a usability test were conducted with sixteen 'acute-to-subacute' post-stroke patients (8 males and 8 females/ age M=49.6, SD=10.1). Participants were randomly assigned to two groups ("OT only" group: a conventional occupational therapy (OT) for 20 minutes at home; "RehabMaster™+ OT" group: 10 minutes RehabMaster™ training plus 10 minutes conventional OT at home). Low-fidelity prototype of RehabMaster™ was installed at each "RehabMaster™+ OT" group participant's home for two weeks (see Figure 4), and both the clinical and usability test were blindly performed.

Figure 4: Installed RehabMaster™ platform at home.

For the clinical test, each group (i.e., "OT only" group and "RehabMaster™+OT" group) was assigned to ten sessions over two weeks. The baselines of the two groups were compared using a Mann-Whitney U test before the main experiment to verify homogeneity of the participants. Then, a Fugl-Meyer Assessment (FMA) for upper limb motor function (0 = lowest score; 66 = highest score) [9] and the Modified Barthel Index (MBI) (0 = lowest score; 100 = highest score) for global function evaluation [16] were used at the baseline (T0), the fifth session (T5), and the last session (T10). Univariate analysis using Mann-Whitney tests was conducted to compare the FMA and MBI score changes between the "OT only" group and the "RehabMaster™+OT" group. All analyses were performed by SPSS software and statistical significance level refers to a $p \leq .05$.

For the usability test, the participants rated the questionnaire (5-point Likert scale) for measuring their control level while performing the rehabilitation procedure at home with RehabMaster™.

RESULTS AND CONTRIBUTIONS

Table 1 shows that two groups can be considered as homogeneous at the baseline (T0).

Table 1: Baseline (T0) characteristics between two groups.

Outcome	OT only (n=7)	RehabMaster™+OT (n=9)	p-value
Age, years	46.6±5.8	52.0±11.9	0.54
Male (%)	3 (42.9)	5 (55.6)	0.[a]
Right-side lesion (%)	2 (28.6)	4 (44.4)	0.[a]
Days after onset	76.6±28.5	67.1±45.3	0.30
Modified Rankin Scale	3.7±0.5	3.2±1.0	0.40
FMA	34.4±12.4	39.4±10.7	0.46
MBI	44.7±9.1	59.9±17.6	0.10

All values are mean±SD.
SD Standard Deviation, *FMA* Fugl-Meyer Assessment, *MBI* Modified Barthel Index
p-values by Mann-Whitney test
[a] p-values by Fisher's exact test

In Table 2, the FMA result shows significant (p=.07) improvement observed in the "RehabMaster™+OT" group than in the "OT only" group. Improvement in MBI (p=.16) was also greater in the "RehabMaster™+OT" group (11.6±6.5) than in the "OT only" group (7.7±4.6). Considering these results, it might be said that RehabMaster™ helped outpatient's upper limb function improvement thanks to the feedforward-based patient autonomy enhancement.

Table 2: Pre-post results from FMA and MBI score.

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
MBI	44.7±9.1	51.0±8.8	59.9±17.6	71.2±15.4

All values are mean±SD.
SD Standard Deviation, *FMA* Fugl-Meyer Assessment, *MBI* Modified Barthel Index

For the usability issues, below Table 3 gives the mean ratings about the perceived control level during the home-based rehabilitation procedure with RehabMaster™. Unlike the previous pilot study which revealed post-stroke patients felt burden in self-choice of the rehabilitation exercises

rather than autonomy-enhancement, the feedforward design was perceived as an active and positive experience.

All the participants mentioned that choosing specific training programme among multiple choices made them to feel in control over entire home-based rehabilitation process (mean 4.5 for Statement 1). They also took RehabMaster™ as meaningful while training (1.3 for Statement 2) and helpful for improving their own health literacy like the current rehabilitation status and expected progress (4.7 for Statement 3). As a whole, nine participants showed a high perceived control level while using RehabMaster™ at home.

Table 3: Perceived control level while employing RehabMaster™ at home (5-point Likert Scale).

Statements	Mean±SD**
1. When choosing among choices, I felt in control over everything.	4.5±1.1
2. I felt that I had no control over my training process with RehabMaster™.	1.3±0.6
3. The RehabMaster™ allowed me to control the whole learning process (e.g., current rehabilitation status and progress).	4.7±1.1

All values are mean ± SD.
**All p-values for the two-tailed test were less than 0.01

Taken together, it might be said that proper feedforward-based design during in-home rehabilitation might foster post-stroke patient's autonomy by balancing system capability and complexity for self-determination.

CONCLUSIONS

While many design factors exist to support user's autonomy, designing autonomy-enhancing rehabilitation platform at home is still challenging. We have identified several design issues to support post-stroke patients' autonomy at home, which we believe is also applicable to other studies of healthcare education.

Figure 5: One week programme recommendation for patient.

- **Cognitive scaffolding:** To support post-stroke patient's autonomy at home, the recommendation for which therapy programme to choose among many possible choices is important (see Figure 5). When outpatients (or their caregivers) select a therapy programme from multiple options under non-controlling instructions at home, it requires them a large amount of cognitive loads. In this regard, a proper level of recommendation for what to do should have an effective scaffolding design. In RehabMaster™, outpatients should have a total reliance to the rehabilitation procedure at an early stage, but at the later stage, they can less rely on the procedure, so they can carry out the rehabilitation process on his or her own [14]. This scaffolding design would foster the outpatient's development of cognitive autonomy and enable them to lead their own self-paced rehabilitation procedure.

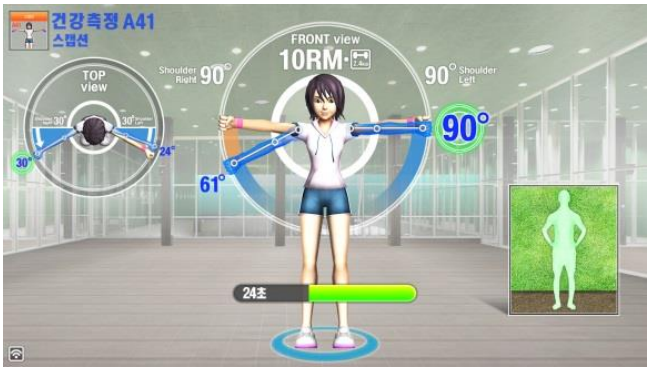

Figure 6: Causal explanation for selected therapy programme.

- **Causal explanation:** For the outpatients and their caregivers, causal explanation about their choice and the expected outcomes are also important (see Figure 6). By understanding anticipated results and progress about their choices, outpatients' perceived locus of control over the entire in-home rehabilitation process can be improved. According to deCharms' theory of personal causation, this perceived locus of causality for choice is critical to harness intrinsic motivation [6]. Self-determination theory [12] also addresses this issue by contrasting autonomous motivation, which is characterized by a sense of agency or personal causation, with controlled motivation. This involves the feeling pressured to behave in a specific way by external forces. In this regard, RehabMaster™ consistently provides causal explanation about each choice option (e.g., post-stroke patient's current status, selected programme's target body part, and expected progress by conducting selected therapy programme) to promote outpatients' sense of ownership about the in-home rehabilitation procedure they are performing.

Figure 7: Positive encouragement from RehabMaster™.

- **Positive persuasion:** Lastly, encouraging outpatients (or their caregivers) during the rehabilitation programme is crucial for autonomy enhancement. By offering feedforward with positive verbal/social persuasions from clinical staff's virtual avatar (see Figure 7: 'You are getting better' or 'You can do this'), the outpatients' self-efficacy for in-home rehabilitation accomplishments can be changed. In addition, subtle text changes from authoritarian tone are also of value (e.g., "Considered a therapy programme for a moment?" vs. "Conduct a therapy programme.") [4]. Bandura's theory of self-efficacy supports this idea by suggesting that the belief about performance accomplishments, verbal/social persuasion and psychological state can boost a person's sense of autonomy [2]. Considering this design issue, RehabMaster™ repeatedly deliver positive persuasions to the outpatients.

In-home therapy is difficult to have certain effects when outpatients do not know what they can achieve and how they can do so (e.g., for outpatients it is hard to understand what to do, how to do, and what will be done during in-home rehabilitation) [17]. As Norman claimed [13], we cannot avoid this complexity issue, but we can control complexity through good design. My study shows that feedforward might be a promising solution to tame outpatient's perceived complexity at home which leads to improved patient autonomy and patient adherence to the in-home rehabilitation. Other similar situations such as fitness and diet control might also employ our proposed design principles (i.e., cognitive scaffolding, causal explanation, and positive persuasion) to foster user's autonomy by balancing system capability and complexity.

The results of this study raise several questions that could be pursued in future work. A longitudinal study will be needed to see how autonomy-enhancement techniques proposed in this study might make a difference in outpatient's rehabilitation performance using longer term measures of rehabilitation outcomes. A rigorous study for feedforward design or how to present anticipated outcomes is also planned in the near future.

REFERENCES

1. Balaam et al. Motivating mobility: designing for lived motivation in stroke rehabilitation. In *Proc. CHI 2011*, ACM Press (2011), 3073-3082.
2. Bandura, A. *Self-efficacy*. John Wiley & Sons, 1994.
3. Burke et al. Optimising engagement for stroke rehabilitation using serious games. *The Visual Computer 25*, 12 (2009), 1085-1099.
4. Calvo et al. Autonomy in technology design. *Ext. Abstracts CHI 2014*, ACM Press (2014), 37-40.
5. Cardol et al. On autonomy and participation in rehabilitation. *Disability & Rehabilitation 24*, 18 (2002).
6. De Charms, R. *Personal causation: The internal affective determinants of behavior*. Academic Press, New York, IN, USA, 1968.
7. Friedman, B. Value-sensitive design. *Interactions 3*, 6 (1996), 16-23.
8. Friedman et al. Value sensitive design and information systems. In *Early engagement and new technologies: Opening up the laboratory*, Springer Press (2013), 55-95.
9. Fugl-Meyer et al. The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance. *Scandinavian journal of rehabilitation medicine 7*, 1 (1974), 13-31.
10. McLean et al. Interventions for enhancing adherence with physiotherapy: a systematic review. *Manual therapy 15*, 6 (2010), 514-521.
11. Neisser, U. *Cognition and Reality*. W.H. Freeman and Co Press, San Francisco, IN, USA, 1976.
12. Nix et al. Revitalization through self-regulation: The effects of autonomous and controlled motivation on happiness and vitality. *Journal of Experimental Social Psychology 35*, 3 (1999), 266-284.
13. Norman, D. A. *Living with complexity*. MIT Press, Cambridge, MA, USA, 2010.
14. Pea, R. D. The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *The journal of the learning sciences 13*, 3 (2004), 423-451.
15. Seo et al. RehabMaster™: A Pervasive rehabilitation platform for stroke patients and their caregivers. In *Pervasive health—state-of-the-art and beyond.* Springer Press (2014), 131-155.
16. Shah et al. Improving the sensitivity of the Barthel Index for stroke rehabilitation. *Journal of clinical epidemiology 42*, 8 (1989), 703-709.
17. Vermeulen et al. Crossing the bridge over Norman's gulf of execution: revealing feedforward's true identity. In *Proc. CHI 2014*, ACM Press (2014), 1931-1940.