Usability Assessment of Neurostim System: A sEMG Activated Neuroprosthesis Remotely Monitorable and Configurable

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RESEARCH

Usability Assessment of Neurostim System: A sEMG Activated Neuroprosthesis Remotely Monitorable and Configurable

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Abstract

Background: The scientific community widely explores rehabilitation techniques for individuals with motor disabilities resulting from a stroke since this condition is observed in millions of individuals worldwide.

Results: This work presents the usability assessment of Neurostim, a neuromuscular electrical stimulation system triggered by a myoelectrical surface signal, with patients with hemiplegia caused by stroke. The device has a Bluetooth connection with a smartphone application so that configuration parameters can be sent. Usage statistics can be captured and monitored remotely by healthcare professionals, which is the innovation of the presented device following the strong tendency to expand the clinical environment to the patient's home. The internet can provide healthcare professionals information to perform a detailed follow-up and interact with their patients remotely. Two control platforms were developed for different user profiles: neuroprosthesis users (Smartphone Application) and health professionals (Web Interface).

Conclusions: Neurostim showed to be a robust system application, despite the need for some improvements. It met all the proposal's expectations, where users were successfully able to operate it, either from a patient or health professional perspective.

Keywords: Electrical Stimulation; Electromyography; User Interface; Stroke; Hemiplegia

¹Background

² Globally, stroke is one of the leading causes of death and long-term disability. It ²
³ consists of a neurological deficit that occurs when there is a lack of adequate blood ³
⁴ flow in a specific area of the brain, either by an obstruction (ischemic, 85% of ⁴
⁵ cases) or rupture (hemorrhagic, 15% of cases) of blood vessels. Factors associated ⁵
⁶ with stroke occurrence include individual habits such as inadequate diet, sedentary ⁶
⁷ lifestyle, smoking, alcoholism, aging, hypertension, and diabetes. Consequently, mo- ⁷
⁸ tor disabilities are commonly observed from brain cells' death in areas responsible ⁸
⁹ for this task [1–3]. ⁹

¹⁰ The damage caused by stroke is directly proportional to its etiology, severity, ¹⁰
¹¹ location, patient age, and associated comorbidities. In less aggressive cases, it is ¹¹
¹² common to see problems such as temporary weakness of limb muscles. In more ¹²
¹³ severe situations, a permanent paralysis on one side of the body or even loss of ¹³
¹⁴ the ability to communicate (expression and interpretation) are typical. In some ¹⁴
¹⁵ cases, with appropriate treatment, it is possible to recover from stroke completely. ¹⁵
¹⁶ However, more than two-thirds of the survivors will have some sequela or disability, ¹⁶
¹⁷ compromising the quality of life [1–3]. ¹⁷

¹⁸ Spasticity is one of the most common impairments after stroke. It is recognized ¹⁸
¹⁹ as a phenomenon of velocity-dependent increase in tonic stretch reflexes with exag- ¹⁹
²⁰ gerated tendon jerks caused by an imbalance of the control signals coming from the ²⁰
²¹ Central Nervous System to the muscles. Therefore, there is a muscular hypertonia ²¹
²² that prevents voluntary activation for the execution of movements. As an example, ²²
²³ the flexor pattern of the elbow, wrist, and fingers is a commonly observed condi- ²³
²⁴ tion in these individuals, that makes it impossible to perform everyday tasks by ²⁴
²⁵ themselves, such as feeding, combing hair, brushing teeth, typing in a computer's ²⁵
²⁶ keyboard, etc. [4, 5]. ²⁶

²⁷ There are numerous reports that the loss of independence is directly associated ²⁷
²⁸ with people's mental health. Here is a considerable decrease in the level of the ²⁸
²⁹ cognitive or emotional quality of life, which can become a picture of depression in a ²⁹
³⁰ short time. This condition undoubtedly influences the rehabilitation process, since ³⁰
³¹ patients undergoing treatment may lose interest in the programs in which they are ³¹
³² inserted [3, 6, 7]. ³²

Over the years, studies such as [8], [9], and [10] have demonstrated the efficacy¹ of Neuromuscular Electrical Stimulation (NMES) for motor sequelae from a stroke.² The study presented in [11] showed that patients who use NMES triggered by sur-³ face electromyography signal (sEMG) could obtain significant improvement in all⁴ functional tests, and their cortical activation was shifted from the ipsilateral sensori-⁵ motor cortex to the contralateral. This phenomenon could not be noticed in patients⁶ who use only NMES, although they also improved in functional tests. In [9], [12],⁷ and [13], there are pieces of evidence for the positive effects of NMES initiated by⁸ sEMG in various configurations. However, [14] presented a systematic review and⁹ meta-analysis of this modality's benefits and concluded that these are larger and¹⁰ evident in chronic cases. In [15, 16], the immediate benefits of donning a myoelec-¹¹ tric elbow-wrist-hand orthosis in chronic, moderately impaired stroke survivors are¹² investigated. The use of the system significantly reduced upper limb impairment¹³ and increased the performance of specific functional tasks.¹⁴

Given the previous considerations, this work's objective is to evaluate the usabil-¹⁵ ity of a neuro-prosthetic system, making it possible not only to use it in places¹⁶ intended for rehabilitation patient's clinic but also at home during the daily life¹⁷ of these individuals. For this purpose, technologies that allow the capture of sur-¹⁸ face electromyography (sEMG) and Neuromuscular Electrical Stimulation (NMES)¹⁹ were used effectively. The sEMG indicates the user's movement intention, while the²⁰ NMES helps to complete the movement. The setup of the parameters, activation²¹ intensity, the current intensity of the stimulation, and mode of use are customizable²² for each user through an application installed on a smartphone. Sending patient²³ information to a cloud database allows health professionals to monitor the device's²⁴ use and send real-time information back to the patient remotely.²⁵

1 Results²⁷

Table 1 contains the results on the pre and post-test questionnaires for patients²⁸ collected respectively at the beginning and the end of the study. In contrast, Table 2²⁹ shows the results for the pre and post-test questionnaires for health professionals³⁰ collected respectively at the beginning and the end of the study. The scale values³¹ used range from 1 to 5, where 1 stands for the "fully disagree" concept, and 5³² represents the "fully agree" concept.³³

1 **TABLE 1 GOES HERE**

1

2 **TABLE 2 GOES HERE**

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5 **2 Discussion**

5

6 Between 55% to 75% of stroke sufferers will remain with upper limb functional
7 limitations after the injury. It will significantly impact the level of dependence on
8 daily life (ADLs) and their quality of life. In our clinical practice, the non-use of
9 the affected upper limb in the ADLs is one of the chief complaints among chronic
10 stroke cases, evidencing the need to develop new interventions focused on the upper
11 limb functional recovery. At the same time, most recent literature shows that upper
12 limb functional recovery can occur even after six months of injury, in the chronic
13 phase, due to task-oriented therapeutic interventions performed intensively and
14 repetitively [17, 18].

14

15 NMES was proposed more than 30 years ago. In recent studies, the method has
16 been enriched; it has been combined with a task-oriented approach and triggered
17 through the voluntary effort. In respect of motor relearning, it is vital to ensure
18 personalized treatment, assistance in complex coordinated tasks execution, daily
19 task performance, but with volitional participation of the patient in task execution,
20 avoiding passive mobilization [18, 19]. In [15, 16], using a myoelectric elbow-wrist-
21 hand orthosis significantly reduced upper limb impairment and increased specific
22 functional tasks' performance.

22

23 Neurostim is a neuroprosthetic device which sEMG trigger the electrical stimulus
24 application that can be used both, in the therapeutic and domestic environment,
25 under the supervision and according to the guidelines and parameters previously
26 provided by the health professional, who can remotely supervise its use, being what
27 sets it apart from the others. Thus, a patient can perform therapy more frequently
28 and also use it during daily task performance.

28

29 Overall, the first impression of the patients, shown by the pre-test questionnaire
30 (Table 1), indicates a good satisfaction level. Question 4 stood out as the furthest
31 from the expected perception, with a standard deviation demonstrating different
32 opinions according to each patient. The assigned low score refers to the fact that
33 the entire assembly of the parts of the neuroprosthesis was done and all instructions

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¹given by the Occupational Therapist responsible for the session so that the patient¹
²could use the application.²

³ As for the complexity of using the system, expressed by patient P1's scores in ³
⁴questions 3 and 8, it is believed that, as he was the only one who had this opinion and⁴
⁵was the first to be presented to the study and to attend the sessions, it could have⁵
⁶been a consequence of the inaugural session and the learning curve of the technical⁶
⁷aspects of the presentation of the device, which was an activity performed by the⁷
⁸responsible for this study. Throughout the other meetings, the other patients did⁸
⁹not have the same impression of this topic. After the tenth session, it was expected⁹
¹⁰that the pre-judgments that could have influenced the first evaluation were remedied¹⁰
¹¹and thus obtained more reliable impressions about the user's actual feelings about¹¹
¹²the system.¹²

¹³ Observing the results of Table 1 – post-test, it can be observed a decrease in ¹³
¹⁴standard deviations, indicating that there was a convergence in patient's opinion¹⁴
¹⁵and significant decrease in the mean value for the column that contains the difference¹⁵
¹⁶between the assigned scores and the desired value, previously in pre-test being 0.55¹⁶
¹⁷points and moving to 0.38 points in post-test. This reduction in the mean value¹⁷
¹⁸indicates that the assigned scores were closer to the expected value, demonstrating¹⁸
¹⁹an increase in familiarity with the system. Patients liked the interface and felt¹⁹
²⁰comfortable using it.²⁰

²¹ However, question 4 continued to stand out as the furthest from the expected²¹
²²perception, and with more patients reiterating the impression that it would take²²
²³the help of a technician to use the device. When questioned, the opinion of all who²³
²⁴expressed themselves negatively revolved around not knowing what value to choose²⁴
²⁵for sensitivity for sEMG when it should be adjusted, even though the values are in²⁵
²⁶a dimensional escalation. This behavior confirms that the presence of a sensitivity²⁶
²⁷selection aid routine would be an essential improvement for future releases.²⁷

²⁸ For question 2, there is an improvement of 1-point for patient P2, converging²⁸
²⁹to the same opinion of patients P3 and P4, and a 2-point worsening for patient²⁹
³⁰P1, which reaffirms his initial perception about finding the system complicated.³⁰
³¹When questioned, the patient states that there was technical implications, but did³¹
³²not know what aspects he referred to, preventing him from using the system. This³²
³³feeling is in agreement and also justifies the scores to questions 4 and 10.³³

¹ For question 6, a 2-point worsening is noted for patient P3. When questioned, this¹
²impression was because the device stopped working at the beginning of the ninth²
³session, which had to be interrupted and subsequently canceled, so that the repair³
⁴could be performed. Undoubtedly, this type of event directly reflects the reliability⁴
⁵that the patient has on the device. ⁵

⁶ ⁶

⁷ For the Occupational Therapists, it is evident from Table 2 that the assigned⁷
⁸scores were more distant from the desired values, showing a more reticent and⁸
⁹critical feeling about the system. Small standard deviations show similar opinions⁹
¹⁰in most of the items evaluated. The perception of Occupational Therapists at the¹⁰
¹¹end of the study also improved, despite remaining more critical. The column's mean¹¹
¹²value that contains the difference between the assigned scores and the desired value¹²
¹³was from 1.53 to 1.33 points. This change was caused by the increase in the score¹³
¹⁴awarded by the OT1 since the OT2 maintained the same scores as in the pre-test¹⁴
¹⁵questionnaire. It is interesting to note that none of the Occupational Therapists¹⁵
¹⁶attributed the maximum score to the presented statements. These results indeed¹⁶
¹⁷indicate that there are still opportunities for improvement. ¹⁷

¹⁸ ¹⁸

¹⁹ Although the evaluation was carried out in a controlled environment, where quali-¹⁹
²⁰fied professionals performed the placement of Neurostim, and with a small sample of²⁰
²¹users, all of them could interact with the system brought evidence of some potential²¹
²²improvements before allowing system application in unmonitored situations: ²²

- ²³ ²³
- ²⁴ • Adjustment of the bracelets that fix the electrodes, integrating them in one ²⁴
²⁵piece, allowing the user to wear it without assistance. ²⁵
 - ²⁶ • Increased drawing area on the Smartphone screen for dynamic objects, making ²⁶
²⁷it easier to interact with buttons, sliders, etc. ²⁷
 - ²⁸ • Confirmation of the end of the procedure before sending data to the server ²⁸
²⁹prevents unexpected stimulation during transmission. ²⁹
 - ³⁰ • Adjustment in the scales of the axis values obtained by the sEMG and values ³⁰
³¹chosen for the sensitivity parameter. ³¹
 - ³² • Confirmation request to end procedure to avoid finishing by an accidental ³²
³³touch on the screen. ³³

13 Conclusion

2 As the main contribution of this work, the literature review showed that a combined
3 initiative between NMES and sEMG applied to a portable device, with the ability
4 to send and receive data connecting to a smartphone application, and providing
5 support tools and remote monitoring for health professionals, had not yet been
6 proposed. The pioneering of this development will undoubtedly stimulate continuity
7 in improving the design and development of related tools. Given the benefits that
8 an integrated solution for low-cost rehabilitation can bring, it is expected that this
9 platform will become versatile enough to make it a continuous use item, outside of
10 rehabilitation activities, being incorporated into the patient's day-to-day life until
11 its use is expendable.

12 Neurostim showed to be a reliable system application, despite the need for some
13 improvements. It met all the proposal's expectations, where users were successfully
14 able to operate it, either from a patient or health professional perspective. Its design
15 was versatile enough for the user to feel comfortable wearing it as a physiothera-
16 peutic element in the rehabilitation center, with intentions of expanding the use to
17 a practical way outside the clinic to help perform daily tasks that are no longer
18 possible due to muscle disability. The smartphone application was designed so that
19 a simple interface allows the user to perform all requested activities with ease, pre-
20 venting eventual errors during the stimulation procedures and avoiding behaviors
21 that would not be expected. The web interface was also developed so the health pro-
22 fessionals can have relevant information about patient's usage and perform detailed
23 analysis to perform adjustments to maximize effectivity to patients' treatment, all
24 remotely.

26 4 Methods

27 4.1 Neurostim

28 Neurostim usage aims to rehabilitate the upper limbs (hands and wrists) of patients
29 with hemiplegia. It is an entirely custom made neuroprosthesis, which relies on the
30 application of Neuromuscular Electrical Stimulation (NMES) activated by surface
31 myoelectric signal (sEMG). NMES and sEMG technologies are extensively known
32 and used in clinical rehabilitation programs. Figure 1 illustrates the device mounted
33 and being used by a user.

Figure 1 Neurostim placed on the user's arm. A smartphone is placed in front of the user so that live data can be seen and usage parameters adjusted as needed.

[scale=0.60]Figures/neurostim.jpg

The innovation corresponds to the proposal of daily use in all environments (not only at the rehabilitation center). For this prospect, two control platforms were developed: one for operating the neuroprosthesis and another platform for remotely monitoring its activities, allowing the health professional to consume data from the device, and to set up parameters of usage, which includes physiotherapy agenda, flow monitoring, and qualitative analysis.

4.2 User Interface

The user interface is an Android smartphone application, built using Android Studio 2.3.3. It is meant to be run in Android versions 4.0 and superior. The application can configure and control the neuroprosthesis with the necessary instructions on the fly. With the electric current application, the extension of wrist and fingers can be achieved when the user's intension of movement is captured through the sEMG circuit.

The application can also act as a bi-directional communication channel between the healthcare professional and the patient, so setups, adjustments of the usage parameters, and information sending about the usage can be made remotely through the internet (either with a Wi-Fi connection or cellular data).

Users of this application present motor function disabilities in one side of their body, commonly causing them to lose the wrist and fingers' movements partially. The interface was developed considering the placement of buttons and dynamic objects on the screen to be easily reachable while using just one hand.

All data is stored locally, considering that the smartphone might not have an active internet connection by the time the procedure ends; thus, synchronization cannot happen. With this mechanism, synchronization can be trigger later on whenever a stable connection is available.

Figure 2 shows one of the application screens that contain the live usage data from a user, where the user can also control the intensity of the electrical stimulation and the sEMG sensibility.

Figure 2 Smartphone application procedure page, showing live information from the current session to the patient.

[scale=0.5]Figures/app.jpg

4.3 Health Professional Interface

The web interface for the health professional was developed in HTML5, PHP, and JavaScript. This interface is a two-way communication channel with the neuroprosthesis, providing the necessary information to configure its use and an instrument of interaction between the patient data and the health professional. By synchronizing the captured neuroprosthesis data from the respective user's smartphones, the healthcare professional can fetch the device's usage history information, so progression analysis from a clinical standpoint can be done and remotely perform the necessary adjustments, as all the data will be stored in a cloud MySQL database.

The web interface can display a significant amount of information in a graphical format, simplifying the data's understanding and providing detailed information as needed for the health professional. It also has tools to automatically indicate to the health professional if the scheduled session was executed following the previously set parameters. Hence, it becomes easier to evaluate the progress and forecast the upcoming sessions of each patient.

Figure 3 shows one of the application screens that contain the usage data from a patient, received right after the user completed the session.

Figure 3 The web interface dashboard shows the usage of data collected by the Smartphone application and sent to the server remotely through the internet.

[scale=0.75]Figures/web.jpg

4.4 User profile

The clinical usability trials were performed with patients over 18 years old, of both genders, with clinical and radiological diagnosis of stroke, motor disabilities in an upper limb due to the presence of right or left hemiparesis, who already be in a rehabilitation program using functional electrical stimulation in muscle groups for wrist and fingers extension and who already use smartphone as a daily routine activity. All the participants were granted in writing of informed consent to participate in the study. It is important to note that not only the patients but also the Occupational

¹Therapists (referred to as Health Professionals) were part of this study, showing the¹
²facilities and difficulties found during the assembly of the neuroprosthesis and the²
³use of the respective interfaces intended for them. ³

⁴ The data collection was done with four patients in the rehabilitation process, all⁴
⁵with right spastic hemiplegia, two were male, and two were female, ranging from 19⁵
⁶to 46 years old. Initially, the objective was to carry out the study with at least ten⁶
⁷patients. However, the inclusion criteria did not allow such amount in the period⁷
⁸available to carry out the study and to provide proper documentation with the⁸
⁹results. The health professional group had two occupational therapists responsible⁹
¹⁰for the selected patients' rehabilitation program's regular activities, both female¹⁰
¹¹being 35 and 56 years old. ¹¹

¹²

¹³4.5 Evaluation sessions ¹³

¹⁴The procedures' objective was to verify whether the developed interfaces are in-¹⁴
¹⁵telligible and accessible to the respective user profiles (patients and health profes-¹⁵
¹⁶sionals), the adequacy of communication, and the neuroprosthesis response to the¹⁶
¹⁷received commands. This research complied with the tenets of the Declaration of¹⁷
¹⁸Helsinki and was approved by the Institutional Review Board at the research ethics¹⁸
¹⁹committee of the HCFMUSP, under the number 00240918.2.0000.0068. Informed¹⁹
²⁰consent was obtained from each participant. ²⁰

²¹ Both patient and health professional were submitted to a presentation session²¹
²²on the proposed usability study, and one evaluation quiz was completed by each,²²
²³according to their personal information and personal characteristics regarding fa-²³
²⁴miliarity with digital devices, technology, frequency of smart devices usage, that²⁴
²⁵could help understand some of the usability results. Pre and post-test question-²⁵
²⁶naires about user profile perception of system usage were also applied for posterior²⁶
²⁷critical analysis. ²⁷

²⁸ The patients were submitted to 10 sessions, these being once a week, lasting one²⁸
²⁹hour each. The session's duration considers the placement of the neuroprosthesis²⁹
³⁰by the therapist, execution of activities requested to both therapist and patient,³⁰
³¹disassembly of the neuroprosthesis, and oral evaluation of the group session. Table 3³¹
³²lists the activities requested for each participant. ³²

³³ **TABLE 3 GOES HERE** ³³

¹ In all sessions, patients were recorded using the application that controls the neu-¹
²roprosthesis. In this way, one could monitor what facilities and difficulties each one²
³had for the given tasks. In the case of Occupational Therapists, the use of the web³
⁴interface was monitored by recording directly from the operating system's graphical⁴
⁵environment using Webex Recorder (Cisco) software. Data were also collected to⁵
⁶identify the eventual difficulties of the users while operating the system. ⁶

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Abbreviations

sEMG - Surface Electromyography
¹³ NMES - Neuromuscular Electrical Stimulation
¹⁴ OT - Occupational Therapist ¹⁴

Availability of data and materials

¹⁵ The datasets generated and/or analysed during the current study are not publicly available due to patient
¹⁶ confidentiality, but are available from the corresponding author on reasonable request. ¹⁶

Ethics approval and consent to participate

¹⁷ This research complied with the tenets of the Declaration of Helsinki and was approved by the Institutional Review
¹⁸ Board at the research ethics committee of the HCFMUSP, under the number 00240918.2.0000.0068. Informed
¹⁹ consent was obtained from each participant. ¹⁹

Competing interests

²⁰ The authors declare that they have no competing interests. ²⁰

Consent for publication

²² Not applicable. ²²

Authors' contributions

²⁴ LMA was the engineer and developer of all platforms presented. Dr. TTT selected the participants based on the
²⁵ acceptance criteria for this project and supervised the sessions from a medical standpoint, along with the vast
²⁶ experience of Dr. LRB. Dr. MCFC masterfully coordinated the study and was a major contributor in writing the
²⁶ manuscript. All authors read and approved the final manuscript. ²⁶

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Tables

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Table 1 Results of the questionnaire for patients

Questionnaire for patients		Pre-test results							Post-test results						
Question	Desired	P1	P2	P3	P4	Mean	Std. Dev.	Diff. to Desired	P1	P2	P3	P4	Mean	Std. Dev.	Diff. to Desired
1. I think I would often use this system	5	5	5	5	5	5.00	0.00	0.00	5	5	5	5	5.00	0.00	0.00
2. I found the system unnecessarily complicated	1	1	2	1	1	1.25	0.50	0.25	3	1	1	1	1.50	1.00	0.50
3. I found the system easy to use	5	1	4	5	5	3.75	1.89	1.25	5	5	5	5	5.00	0.00	0.00
4. I think it would require the support of a technician to use this system	1	4	2	4	1	2.75	1.50	1.75	5	4	5	1	3.75	1.89	2.75
5. The functions of this system were well integrated	5	5	4	5	5	4.75	0.50	0.25	5	5	5	5	5.00	0.00	0.00
6. I found this system very inconsistent	1	1	2	1	2	1.50	0.58	0.50	1	2	3	2	2.00	0.82	1.00
7. I imagine most people would learn to use this system quickly	5	5	4	5	5	4.75	0.50	0.25	5	3	5	5	4.50	1.00	0.50
8. I found the system too complicated to use	1	4	2	1	1	2.00	1.41	1.00	1	1	1	1	1.00	0.00	0.00
9. I felt very confident with the system	5	5	5	4	5	4.75	0.50	0.25	5	5	4	5	4.75	0.50	0.25
10. I need to learn a lot of things before I continue using this system	1	2	2	1	1	1.50	0.58	0.50	4	1	1	1	1.75	1.50	0.75
11. I felt comfortable with this system	5	5	5	4	5	4.75	0.50	0.25	5	5	5	5	5.00	0.00	0.00
12. It was easy to find the information I needed	5	5	4	4	5	4.50	0.58	0.50	5	5	5	5	5.00	0.00	0.00
13. I liked using this interface	5	5	4	4	5	4.50	0.58	0.50	5	5	5	5	5.00	0.00	0.00
14. The system interface is nice	5	5	4	4	5	4.50	0.58	0.50	5	5	5	5	5.00	0.00	0.00
15. The organization of information on the interface screen is clear	5	5	4	4	5	4.50	0.58	0.50	5	5	5	5	5.00	0.00	0.00

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Table 2 Results of the questionnaire for Occupational Therapists

Questionnaire for Occupational Therapist		Pre-test results						Post-test results					
Question	Desired	OT 1	OT 2	Mean	Std. Dev.	Diff. to Desired		OT 1	OT 2	Mean	Std. Dev.	Diff. to Desired	
1. I think I would often use this system	5	4	5	4.5	0.71	0.50		4	5	4.50	0.71	0.50	
2. I found the system unnecessarily complicated	1	2	2	2	0.00	1.00		2	2	2.00	0.00	1.00	
3. I found the system easy to use	5	3	4	3.5	0.71	1.50		4	4	4.00	0.00	1.00	
4. I think it would require the support of a technician to use this system	1	3	4	3.5	0.71	2.50		2	4	3.00	1.41	2.00	
5. The functions of this system were well integrated	5	4	4	4	0.00	1.00		4	4	4.00	0.00	1.00	
6. I found this system very inconsistent	1	2	2	2	0.00	1.00		2	2	2.00	0.00	1.00	
7. I imagine most people would learn to use this system quickly	5	4	3	3.5	0.71	1.50		4	3	3.50	0.71	1.50	
8. I found the system too complicated to use	1	2	2	2	0.00	1.00		2	2	2.00	0.00	1.00	
9. I felt very confident with the system	5	3	3	3	0.00	2.00		4	3	3.50	0.71	1.50	
10. I need to learn a lot of things before I continue using this system	1	2	4	3	0.00	2.00		2	4	3.00	1.41	2.00	
11. I felt comfortable with this system	5	4	4	4	0.00	1.00		4	4	4.00	0.00	1.00	
12. It was easy to find the information I needed	5	3	3	3	0.50	2.00		4	3	3.50	0.71	1.50	
13. I liked using this interface	5	3	4	3.5	0.50	1.50		4	4	4.00	0.00	1.00	
14. The system interface is nice	5	3	2	2.5	1.00	2.50		4	2	3.00	1.41	2.00	
15. The organization of information on the interface screen is clear	5	4	2	3	0.47	2.00		4	2	3.00	1.41	2.00	

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Table 3 Tasks to be executed

Task	Executor	Description
T1	OT	Mount the neuroprosthesis on the patient
T2	OT	Create / check / modify the patient parameter setting schedule
T3	Patient	Perform in-app user authentication
T4	Patient	Start procedure (perform finger and wrist ex- tension)
T5	Patient	Adjust procedure parameters
T6	Patient	End procedure
T7	OT	Disassemble the orthosis from the patient
T8	OT	Check patient procedure data

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Figures

Figure 1

Neurostim placed on the user's arm. A smartphone is placed in front of the user so that live data can be seen and usage parameters adjusted as needed.

Figure 2

Smartphone application procedure page, showing live information from the current session to the patient.

Figure 3

The web interface dashboard shows the usage of data collected by the Smartphone application and sent to the server remotely through the internet.