Open Rehab Initiative: design and formative evaluation

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ABSTRACT

Development and testing of virtual environments for rehabilitation is a lengthy process which involves conceptualization, design, validation, proof concept testing and ultimately, if appropriate, randomized controlled trials. Ironically, once vetted, many of these VEs are not available to clinicians or their patients. To address the challenge of transferring research grade technology from the lab to the clinic the authors have created the Open Rehabilitation Initiative. It is an international independent online portal that aims to help clinicians, scientists, engineers, game developers and end-users to interact with and share virtual rehabilitation tools. In this paper, the conceptualization, development and formative evaluation testing are described. Three groups of developers of VEs (n=3), roboticists who use VEs for robot interactivity (n=10) and physical therapists (n=6) who are the clinicians end-users participated in the study. Interviews, focus groups and administration of the SUS were used to assess acceptability. Data were collected on three aspects, 1) discussion of what a resource might look like, 2) interaction with the site, and 3) reaction to the proposed site and completion of the SUS. Interviews and focus groups were recorded and transcribed. Data from the SUS was analyzed using a One-way ANOVA. There was no significant difference by groups. However, the clinicians' mean score of 68 on the SUS was just at the acceptable level, while the developers and roboticists scored above 80. While all users agreed that the site was a tool that could promote collaboration and interaction between developers and users, each had different requirements for the design and use. Iterative development and discussion of scaling and sustaining the site is ongoing.

1. INTRODUCTION

Development testing of virtual environments (VEs) for rehabilitation is a lengthy process, which involves conceptualization, design, validation, proof concept testing and ultimately, if appropriate, randomized controlled trials. Often, once the technology has been developed and tested for a specific application, it is discarded. This results in a lack of transfer of the technology to the clinician at the point of care. Several explanations exist for the lack of transfer. One explanation is that the technology was not developed with the end-user in mind and therefore uses hardware that may not be readily available to persons in clinical practice. Another explanation is that the route to commercialization is expensive and lengthy and many scientists are not interested in pursuing this avenue. In this paper we propose the development of an international community as a solution, the Open Rehab Initiative (ORI), whereby developers may share their technology with clinicians.

As the virtual rehabilitation field evolves and technology becomes more accessible and available, the authors believe, it is increasingly important to find mechanisms to coordinate and bring together clinicians, scientists and engineers to interact with and share their efforts with virtual rehabilitation tools. Recent reviews support the use of virtual rehabilitation training in people with neurological diagnoses (Pietrzak et al., 2014; Laver et al., 2015).

However, a large part of the implementation of VR in rehabilitation is limited to work developed in the context of research projects - which does not reach end users, in particular clinicians and patients. Currently what is available to clinicians are the results of efforts to repurpose commercial games available for game consoles by providing clinicians with tools to adapt the Wii™ (Deutsch et al., 2011) and online resources on how to use the Adventure Games for the Kinect™ (Levac et al., 2015). Resources are also made available by clinicians or researchers themselves through blogs or structured websites where hardware and software lists - mostly commercial Wii™ or Kinect™ games, and sometimes companies developing bespoke rehabilitation systems - are shared together with therapy game suggestions, ratings and tips (Leynse Harpold, 2016; Scott, 2016; TherapWii, 2016).

In implementation sciences, researchers have studied transfer knowledge as well as support of clinical reasoning by using online resources (Deutsch et al., 2015). The use of these resources for knowledge translation has been associated with positive behavior change in healthcare workers including nurses, physicians, physical therapists, and occupational therapists (Magrabi et al., 2004; McKenna et al., 2005; Grimshaw et al., 2006; Honeybourne et al., 2006). Unfortunately, less work can be found in the systematic transfer of virtual environments and serious games technology from developers to users. Multiple efforts exist in the creation of indices of games specially designed for specific health purposes (Lieberman et al., 2013; Serious Games Association, 2016). Unfortunately, available indices do not refer to literature specific to the applications and, consequently, the use of such games and applications is mostly not validated. On the other hand, other initiatives such as Games for Health and Games for Health Europe (van Rijswijk et al., 2016) feature a limited number of research projects with detailed descriptions and information regarding their target population and scientific outcome. However, in most cases content is unavailable to the clinician and end user. Consequently, there is still a large body of work on validated and research-driven technology that remains unavailable to clinicians and patient populations. There is therefore the need to facilitate the translation from research into daily clinical practice and to create new communication channels and a common framework to share and improve interventions in this area.

The ORI is an international independent initiative that aims to help clinicians, scientists, engineers, game developers and end-users to interact with and share virtual rehabilitation tools. The ORI portal is planned as a hub where the community who build and use software tools for virtual rehabilitation can easily communicate, interact with and share these tools. The webpage currently offers software, drivers, and documentation of evidence and application, with support for discussion boards, and blogs. Although ORI originates from academic institutions, it is designed to grow through community driven content, incorporating inputs from all the relevant communities. This sentiment is reflected in the ORI mission statement: ORI's mission is to become *"the go-to community for clinicians, scientists, engineers, game developers and end-users to interact with and share virtual rehabilitation tools"*. As such, we aim to attract both developers and virtual rehabilitation users, for research as well as for clinical practice. The scope of the simulations encompasses sensorimotor and cognitive rehabilitation.

The objective of this study was twofold: first, to describe the conceptualization and preliminary rendering of the ORI site; and second, to report on the formative evaluations conducted on three groups of users: clinicians in a rehabilitation setting, developers (clinician scientists and engineers) of VEs for rehabilitation and an engineering group that develops robotic devices that have serious game interfaces. As developers and roboticits have a certain degree of technical expertise and would be both contributors and users to the site, we anticipated that their assessment of the site capability as well as the usability ratings would differ from those of the clinicians.

2. METHODS

2.1 Overview

The ORI started as a multidisciplinary effort of the RiVERS Lab (Rutgers University, USA), the NeuroRehabLab (Madeira-ITI / University of Madeira, PT), and the Neurorehabilitation and Brain Research Group (i3B, Universitat Politècnica de València, SP). The conceptualization of the site originated with the founding members, to create the infrastructure, goals and a preliminary website. A user-centered formative evaluation informed the first iteration of the ORI (Usability Professionals' Association, 2016). Input was sought through user studies representing different communities that would be both contributors and users of the site. In this first iteration the person receiving therapy was not included.

2.2 Web design

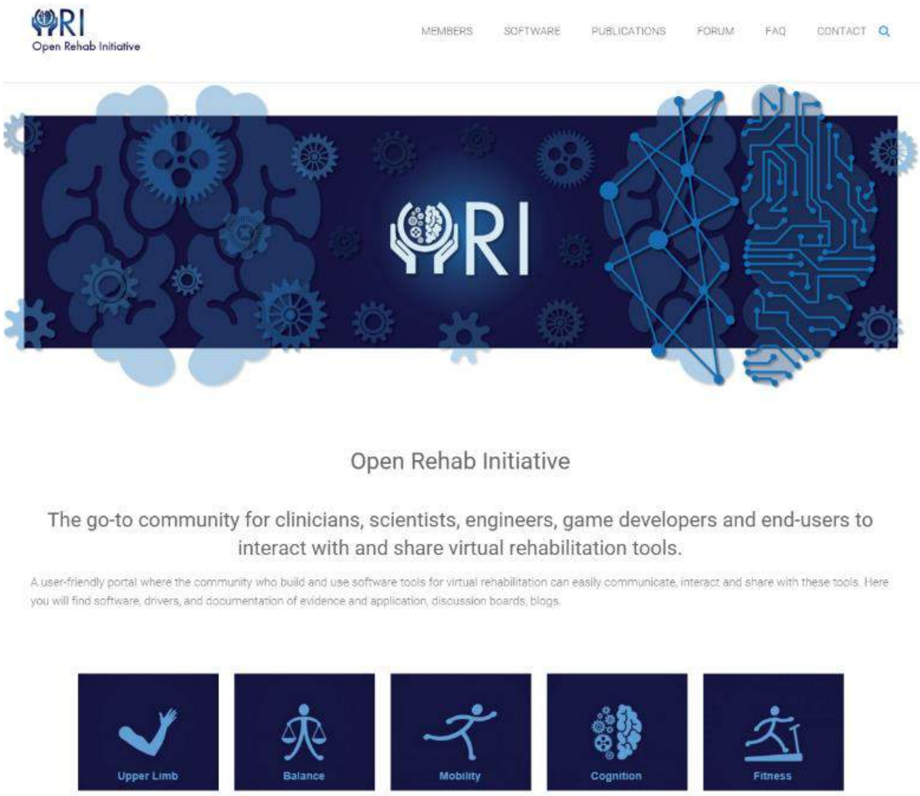
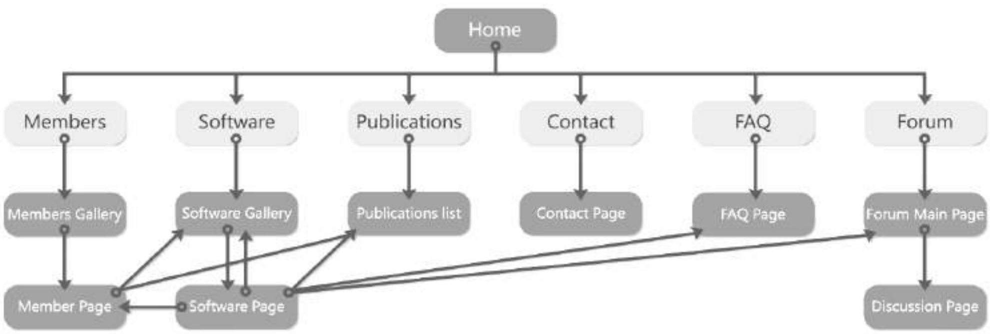


Figure 1. *The Open Rehab Initiative landing page. Content is organized according to the following taxonomy: Upper Limb, Balance, Mobility, Cognition and Fitness.*

ORI is a unified place to share and find all information related to the available applications (Figure 1). Applications are organized according to the following domain taxonomy: Upper Limb, Balance, Mobility, Cognition and Fitness, and their different purposes: Rehabilitation, Wellness or Assessment. Applications can be commercial/free, closed/open-source, but all have a contact person available for support and a dedicated forum available for inquires (Figure 2a). ORI currently hosts 3 different applications free of cost: the NTT for upper limb motor training (Bermúdez i Badia et al., 2012; Bermúdez i Badia et al., 2014), VSTEP for balance, mobility and fitness training (Gosine et al., 2015), and a posturography assessment instrument (Llorens et al., 2016). All applications in ORI are organized in a concise manner in a table characterized by their name, application domains, purposes, compatible hardware, software drivers, cost, and related publications as shown in Figure 2b.



a)

	Software	Domain	Purpose	Compatible Hardware	Compatible Software/Drivers	Cost	Publications
	NTT - Neurorehabilitation Training ToolKit	Upper Limb	Rehabilitation	AnTS, Keyboard, mouse, Kinect v1, Wiimote, mPower 1000, AR	Reh@Panel	Free	1, 2
	VSTEP - Stepping Game	Fitness, Balance, Mobility	Rehabilitation and wellness	Kinect v1		Free	1
	Posturography	Balance	Assessment	Wii Balance Board		Free	1

b)

Figure 2: *Open Rehab Initiative content: a) website structure and b) the first 3 initial applications.*

In addition to the table summary view, each application has a dedicated webpage where extended information is available about the application and its usage (Figure 3). The dedicated webpage contains a detailed description of the application with a video and/or several screenshots, detailed installation guidelines as well as requirements for its installation, license information and a link to the application in a downloadable format. A Frequently Asked Question (FAQ) section contains the most common questions and answers for each application. In addition, a forum enables further interaction with the application developers and other users of the community. All of this content is crosslinked in such a way that all information about each application is at most one click away from their dedicated page.

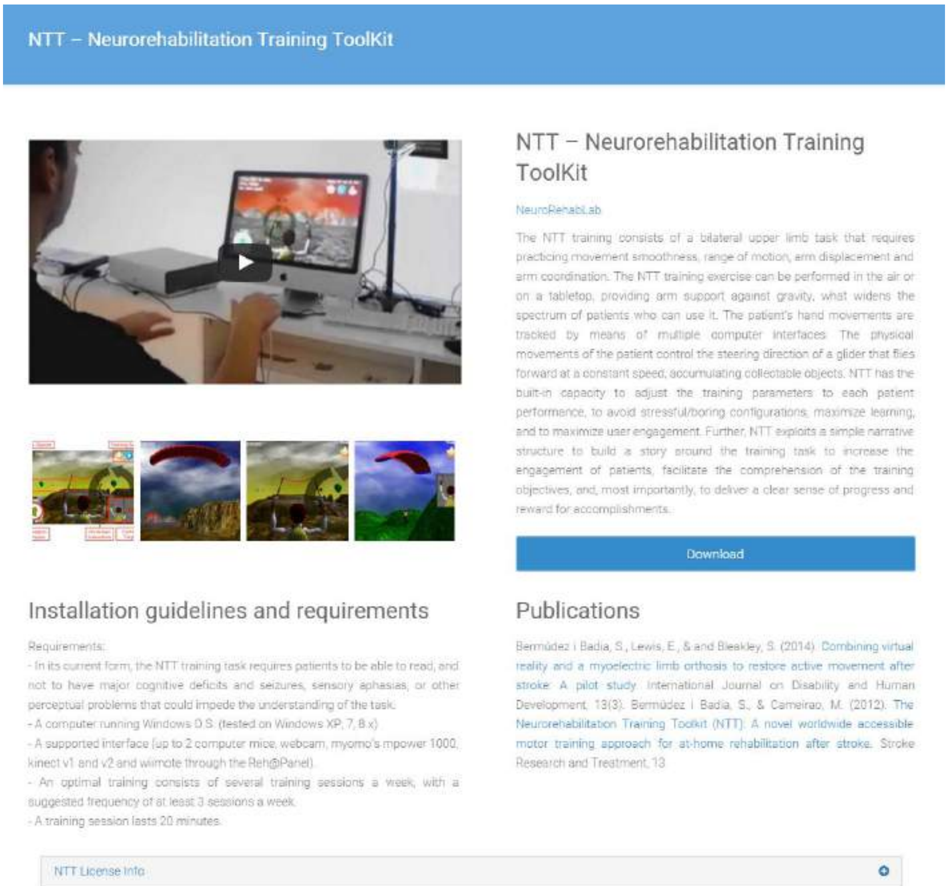


Figure 3*: Example webpage of the Neurorehabilitation Training Toolkit (NTT) featuring a description, installation guidelines, related publications, license information and link to the downloadable application.*

2.2 Participants

Three groups of participants were included in this study: clinicians (n=6), roboticists (n=10), and VE developers (n=3). The rationale for selecting the three groups was based on the anticipated diversity of users, namely those who may contribute to the site, such as developers in the field or persons in adjoining fields that use serious games (roboticists) and those who would use the technology, such as clinicians. Clinicians were recruited from the Servicio de Neurorrehabilitación y Daño Cerebral of NISA Hospital Valencia al Mar (Valencia, Spain). Participants in this group were 31.8±5.5 years old, had more than 2 years of experience in neurorehabilitation (11.3±5.5 years), and had a variable experience with virtual reality and serious games (4.3±4.0 years). Roboticists were recruited from the University of California Irvine (Irvine, CA, United States). They were high school, masters and PhD students, post-doctoral fellows and faculty. The majority were engineers. They ranged in age from 18 to 45 years. Developers included two engineers, who were recruited from Universitat Politècnica de València, and a clinician scientist, recruited from Rutgers University. They were 47.3±3.8 years old, and had more than 10 years of experience in the field.

2.3 Procedure

Data were collected in two formats: focus groups for the clinicians and roboticists and individual interviews with the VE developers. Both focus groups and interviews were divided in three parts. In the first part, participants were informed about the objective of the ORI webpage and then were asked what their desired features for such a site were. See the specific questions in (Table 1. Part A). Second, clinicians were given a case of a person post-stroke and freely reviewed the site to find applications to work with the patient. Developers and roboticists were asked to select one of the applications, look through it, and assess it for clarity, ease of use and implementation. Third, after 5-10 minutes of free use of the site, participants rated the usability of the system and completed the second part of the interview about their response to interaction with the website (Table 1. Part B)

Table 1. *Interview Questions*

Part	Focus groups - Clinicians and roboticists	Individual interviews - Developers
A	1. If you were to have a website where you could get video games or virtual environments for rehabilitation, what would it look like? 2. What would be the most important thing of it for you? 3. What features would you like 4. What information about the video games and virtual environments would you like to have? 5. Do you think the site should all be for free or would you be willing to pay for it? 6. Would you need technical support? 7. Would a discussion board be useful? 8. Would a Frequently Asked Questions section be useful?	1. Would your group participate in the initiative? Why or why not? 2. Would you share your video games or virtual environments for free? a. If yes, do you think the site should all be for free? b. If not, what would you want in exchange? 3. Right now what can you envision that your group would share? 4. If you were to contribute to this site. What instructions would you want to have in order to smoothly share your content? 5. What procedure would you use to populate the site with content? 6. What metrics on use would you find helpful? 7. Do you think this concept could increase the access to virtual reality and video games?
B	1. Do you think there is enough information to use it? If not, please specify what is missing. 2. What are the barriers to using this type of website in your practice setting? 3. What suggestions do you have for improving the site?	1. Please give us your input on the site. 2. Now that you have seen the site. Would you be interested in contributing to it? If not, please tell us why.

The usability of the system was assessed with the System Usability Scale (SUS) (Brooke, 2013). The SUS is a simple ten-item scale that serves as a global assessment of subjective usability. It employs a Likert scale with scores ranging from 0 to 100. Differences in usability scores between the three groups were assessed with a One-way analysis of variance. Statistical significance was set with an alpha of .05. Usability scores above 68 in the SUS questionnaire are considered to be above average (Brooke, 2013). Interview transcripts were reviewed and comments were summarized.

3. RESULTS

3.1 Desired features of the site

3.1.1 Clinicians. Their top request was simplicity of use, and considered accessibility and visual information as the most relevant factors to facilitate interaction with the site. Clinicians also reported that the site should categorize the software by relevant treatment areas (such as balance and upper limb use) to make searching easier. With regards to their clinical practice, clinicians would appreciate any information relating to indications and contraindications, dosage and average duration of treatment, as well as any scientific evidence of the efficacy of the software tools. Clinicians reported that the provision of videos of patients interacting with the video game or virtual environment would help them to understand the purpose of the training. They also suggested that the site should provide ratings both on the quality of the software (has it indications and contraindications, scientific evidence, a video demo, etc.?), and, on other clinicians' subjective impression of the software. In line with this, clinicians wanted a discussion board to share experiences and get feedback from their colleagues. Finally, clinicians reported a decreased self-efficacy with technology and indicated that they would require technical assistance to guarantee a successful use of the site.

3.1.2 Roboticists. This group's top request was that virtual environments be simple and allow multiple inputs. They wanted games or VEs to be played in a way that data would be collected and sent to the investigators. They preferred the code to be open source. They requested filter tags. As a criterion for uploading on the site, they suggested that a pool of reviewers test it and vet it. The criteria for keeping the games on the site would be based on the ratings of the clinician. They also wanted a section of the site to have open data that could be shared.

3.1.3 Developers. Engineers and a clinician scientist were willing to participate in the ORI to share clinically relevant simulations, to disseminate the results of their efforts, to find clinical population to validate their software or to run multicentre studies, and to learn about clinicians' needs as well as get feedback from clinicians on specific applications. Even though they were inclined to share their software for free, they drew attention to the fact that some VEs developed under the framework of public or private grants or projects could not be shared due to licensing issues. Engineers reported, on one side, that the site should make the use of the software very accessible and easy for clinicians, and pointed out that the site should provide user's manuals and technical documents with this purpose. On the other side, they were interested in knowing the number of downloads and, beyond this, the profiles of the users and their feedback as well as for which population the application had been selected. The clinician scientist felt there should be a minimal standard of reliability as the criteria for uploading content to the site. All the developers found the ORI website to be a promising way to increase the access to VEs for rehabilitation, were interested in sharing their software, and identified conferences and social media as the main actors to publicize it.

3.2 Reaction to the Site

3.2.1 Clinicians. Participants in this group reported that there was enough information to use the ORI webpage and identified four threats that could limit their use in the clinical practice: first, restricted internet access of some medical centers; second, unreasonable cost of the VEs or serious games; third, excessive advertising (banners, pop-ups, etc.) that would affect the usability of the site; and fourth, infrequent online content update. Finally, clinicians suggested that the site should prioritize any visual information.

3.2.2 Roboticists. Aside from very small bugs, they found the site very useful. They wanted a forum in which you could contact the author of the software. They were very interested in having the code available so there could be further development.

3.2.3 Developers. Developers highlighted the simplicity of the website and emphasized the responsiveness of the web site to provide an optimal viewing and interaction experience on all devices (desktops, tablets, phones, etc.). In this line, they pointed out that a larger font size would help to read some sections. The clinician scientist felt there was more information there that he needed, but he could filter it out. Some of the images had little contrast and were difficult to read. Finally, consistently with their reports before interacting with the website, they reported the importance of a discussion forum to contact clinicians and developers with each other. The clinician scientist reported that he associated the quality of the site with the investigators who had designed it. He revisited his point about the robustness of the application and the amount of testing it has as the criteria for uploading on the site. The idea of preferentially listing the applications that were free as well as including those for a cost appealed to him.

3.3 Usability Ratings

Developers and roboticist reported the highest scores (88.3±7.2 and 81.7±15.8, respectively), well above the suggested cut-off of 68, defining the webpage as acceptable in terms of usability. In contrast, clinicians rated the webpage with lower scores (68.7±5.8). Differences among groups were not statistical significant.

The mean scores of each group to the items of the SUS are shown in the Table 2.

Table 2. *Results of the three groups in each item of the SUS. Data are expressed in means.*

Users	SUS1	SUS2	SUS3	SUS4	SUS5	SUS6	SUS7	SUS8	SUS9	SUS10	Total
Clinicians	3	3	2.5	2.5	3	2.5	3	3	2	3	68.7
Roboticists	2	4	4	3	3	4	4	4	3	3	85
Developers – Clinician scientist	3	4	3	3	2	3	3	4	3	4	80
Developers – Engineers	4	4	3	4	3	4	3	4	4	4	92.5

3.4 Observations of Users' Interaction with the Site

3.4.1. Clinicians. This group found the upper limb application without any help. However, even though they were able to navigate the site, they repeated that some clinicians, especially if they are not used to serious games, might need assistance during the process. While using the site they also expressed that it would be useful to have information about "how many people are using each application".

3.4.2. Roboticists. This group immediately went to the heading software and selected an upper limb application. This is consistent with their area of work. When queried if they cared who had developed the site, their answer was no. They viewed the video before reading any sections of the text.

3.4.3 Developers. Engineers went through the posturography application and found the website "very simple to use" and considered all the information available "very valuable". After exploring other areas they showed suggested a re-organization of the areas. They suggested that if a there were many categories for the software on the site, that the classification be layered rather than showing them all at once. Specifically, one could have a main division between motor and cognitive applications, and then specific categories for each domain (upper limb, balance, etc. in the motor domain and attention, memory, etc. in the cognitive domain).

The clinician scientist found the upper limb application and watched the video. He was familiar with the application and the video and commented "I like this application". He did not feel he needed all the text. When encouraged to look at another simulation he found the posturography written descriptions to be very clear and commented "this would be very useful for a clinician". The images for this software were less clear.

4. CONCLUSIONS

As anticipated the three groups that were tested responded differently to the site although there was general agreement that the site would be worthwhile. The developers and roboticists had higher usability scores compared to the clinicians that just made the acceptability cut off.

Contributors to the site found that the site would be a powerful tool to overcome the gap between the development of virtual environments and serious games and their usage, and found the site usable with ratings of 80, above the satisfactory cut off rating. They were amenable to share their software and were equally comfortable with the software on the site being free or having a cost. Importantly, their desire to have feedback from the clinicians, not only about their use but also about their needs, and suggested the implementation of communication channels and forums for discussion. Importantly the contributors have indicated that they seek interactivity with the end-user as well as the other contributors.

Clinicians approved of the purpose of the initiative and showed interest in using the site. They, however, experienced a lack of self-confidence during the interaction, which may explain their lower usability scores. This decreased self-efficacy when clinicians interact with technology has been observed by others (de Joode et al., 2012). It is evident that the resource needs some revision and simplification to meet the needs of the clinician end-user. Clinicians offered specific suggestions to improve the site, such as: simple and clear explanations, prioritizing the use of visual information (videos, overall), adding tutorial and providing the technical assistance for unexperienced clinicians.

Given the initial approval by colleagues in and outside the field, the next logical step is to solicit input from the community of VR developers at our professional meetings, namely ICDVRAT and ICVR. It will be important to survey the community to determine who would be willing to contribute simulations and how would such a resource be implemented and funded. Thus, user feedback will inform the next iteration of the ORI site. Several important questions need to be addressed with regards to the acceptance of contributions: 1) what will the minimal requirements for eligibility to post on the site be? 2) How will the quality be rated? In addition, the acceptance of work-in-progress software, with dynamic and open-source contributions, and how to differentiate these applications from finalized software with stable and robust products for clinical use is still on debate. Our original intent was to support the clinician and thus we would require stable and robust products for clinical use. Alternatively, we can tag products in development to allow the end-user to shape the product. Future improvements of the site will also enable contributors and clinicians to leave their feedback. Perhaps we will require separate rating systems by clinicians and developers. Important decisions about balancing sustainability of the site and meeting the needs of the clinician as well as the developer have emerged from this study. These considerations will likely shape the future design of the site.

Acknowledgements: The authors wish to thank Teresa Paulino for the design and programming of the website, the staff of the Neurorehabilitation Unit of Hospital NISA Valencia al Mar and the Department of Biomedical Engineering at University of California Irvine for their involvement in the study. This study was funded in part by Ministerio de Economía y Competitividad of Spain (Project NeuroVR, TIN2013-44741-R and Project REACT, TIN2014-61975-EXP), by Universitat Politècnica de València (Grant PAID-10-14), by the European Commission through the RehabNet project - Neuroscience Based Interactive Systems for Motor Rehabilitation - EC (303891 RehabNet FP7-PEOPLE-2011-CIG), and by the Fundação para a Ciência e Tecnologia through SFRH/BD/97117/2013 Projeto Estratégico - LA 9-2015-2016.

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