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Virtual Coaching for Home Rehabilitation – Evidence of an Empirical Study

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Abstract. Older individuals often face disabilities or diseases that lower their quality of life (QoL). While inpatient rehabilitation can initially enhance QoL, there is often a lack of continuation at home. Virtual coaches (VCs) as specific embodied conversational agents promise appropriate support for home rehabilitation. They emerge as complementary digital aids to ensure care continuity. This paper presents the results of implementing a full-featured VC for older patients' home rehabilitation in a multi-stage study, summarizing the main results regarding QoL outcomes and user experience tests. The study confirms the intervention as an engaging means for rehabilitation (mostly above user experience thresholds) and improvements of QoL (>10% between experimental and control groups).

Keywords. Virtual Coaching, Digital Health, Rehabilitation Care

1. Introduction

Patients often need rehabilitation after acute incidents or chronic diseases to improve their quality of life (QoL). The shift from hospital to home can disrupt care continuity.

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Virtual coaches (VCs) in the form of embodied conversational agents can provide personalized home rehabilitation programs to regain independence and societal involvement [1,2]. The EU-funded *vCare*[2] project developed and tested such a VC solution that comprised a human-like rendered avatar on a tablet for exercise reminders, hints for leisure and healthy lifestyle, and cognitive and physical serious games. The project aimed to improve QoL by at least 10% as its primary clinical outcome.

Generally, evidence on the design of VCs and their advantageousness in the medical domain is rare, especially regarding randomized controlled trials [1]. Lacking evidence, research may struggle to find fit-for-purpose solutions [3]. Developing comprehensive, sustainable VC solutions and demonstrating their technical feasibility and clinical outcomes for different disease settings is rather unexplored [2]. This lack of evidence is addressed by the following research question: *To what extent do VC-based rehabilitation systems positively influence rehabilitation concerning user experience and QoL?*

The article at hand summarizes the main findings of an extensive study [4]. It reports the results of the user experience and QoL tests during the concluding Pilot Phase.

2. Methods

An iterative, tripartite evaluation strategy was conducted to investigate the effectiveness of the VC for home rehabilitation. Firstly, in the *Tech Lab Phase*, the functioning and stability of the technical components were tested. In the following *Living Lab,* the VC system was tested in research apartments, providing a protected environment and support for the patients using the VC solution. In the final *Pilot Phase* (focus of this article)*,* the patients used the solution in their home environment. Three participating clinical sites specialized in cardiological (heart failure, ischemic heart disease in Romania) and neurological (stroke in Italy, Parkinson's disease in Spain) pathologies recruited the patients. Study participants were selected from each site's patient base with defined inclusion criteria (e.g., less severe symptoms not precluding independent participation) and were asked to participate in the study voluntarily. The Pilot Phase was planned as a *small-scale pilot randomized trial* [5]. Ten participants per pathology followed a personalized home rehabilitation program for up to three months (*experimental group*) and conducted physical and cognitive training delivered via the coaching app. The patients also utilized the VC to receive exercise reminders, monitor vital signs, and access e-learning materials. Ten additional patients per pathology received conventional rehabilitation (i.e., clinical recommendations at discharge; *control group*). In sum, 80 patients have been involved. The *EQ5D* scale[3] has been used to compare QoL pre- and post-intervention. The User Experience Questionnaire (*UEQ*) assessed pragmatic (efficiency, perspicuity, dependability) and hedonic aspects (novelty, stimulation) [6].

3. Results

Table 1 provides details on the participants of the Pilot Phase as recruited by the clinics. The study's outcomes varied slightly depending on the pathology and EQ5D subscale.

[2] See the project website for more details (last accessed: 08 May 2024): https://vcare-project.eu/

[3] See for details and a demo here (last accessed: 08 May 2024): https://euroqol.org/eq-5d-instruments/

However, the VC system was instrumental in facilitating the recovery of QoL, particularly in improving continuity of care, providing personalized cognitive and motor exercises, and offering comprehensive coaching advice.

Table 1. Overview of the Pilot Phase participants (different usage times between 09/2021-06/2022).

	Stroke	Parkinson Disease	Heart Failure	Ischemic Heart Disease
Experimental group	7 male, 3 female, age: 72.50 ± 9.00	7 male, 3 female, age 64.50 ± 7.90	6 male, 4 female, age: 60.81 ± 10.87	10 male, 0 female, age: 58.10 ± 7.10
Control group	7 male, 3 female, age: 72.20 ± 11.80	7 male, 3 female, age: 69.10 ± 3.50	6 male, 4 female, age: 59.60 ± 7.99	7 male, 3 female, age: 58.00 ± 7.21

Figure 1 compares the summative QoL scales pre- and post-intervention (for indicative purposes only showing the general decreasing trend in the data). For example, the mobility score for the stroke case decreased from an average of 2,0 to 1,7 (pre- to post-intervention), leading to an improvement of about 17%. The study was primarily exploratory and designed to investigate the potential benefits of the VC solution. Still, there is a clear trend toward improvement, given that the scale is a first indicator of the advantage of the VC solution.

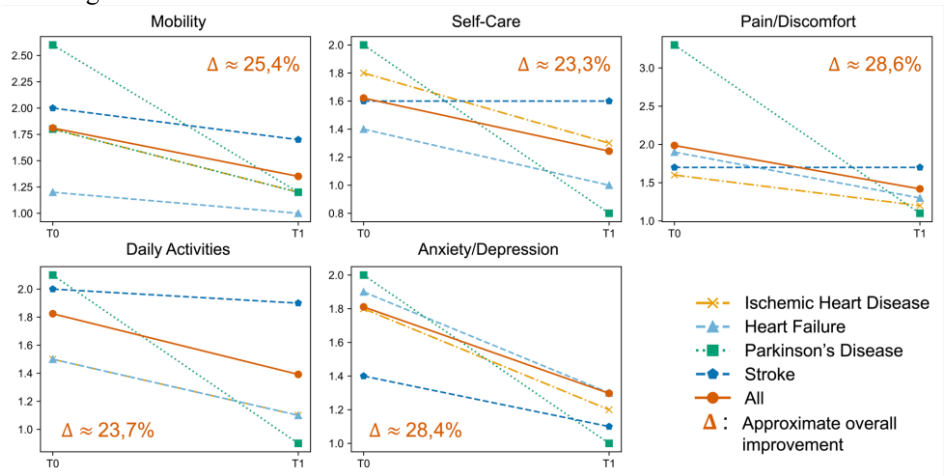

Figure 1. Comparison of the EQ5D QoL scales pre (T0) and post (T1) pilot phase intervention. The scores range from 0 (no problems) to 4 (unable to walk, unable to perform daily activities, etc.; from [4]).

Figure 2 illustrates the EQ5D-VAS ratings measuring patients' perceived health status in the VC-guided and traditional interventions (again, the focus is on the general trend).

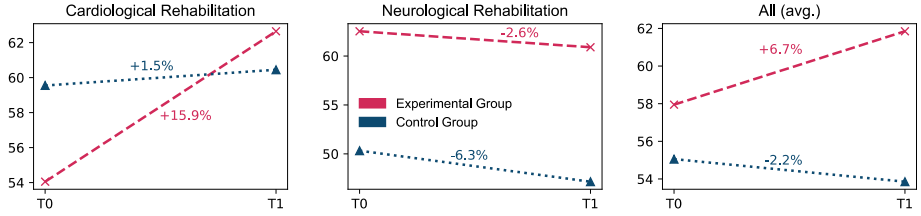

Figure 2. Changes in the EQ5D-VAS Scale (perceived health status) of the experimental and the control group for the cardiological and neurological rehabilitation program as a measure of overall effectiveness [4].

Despite the limited sample size, both patient groups (neurological and cardiological) had similar treatment needs and rehabilitation. Therefore, the data have been pooled for a comprehensive assessment. The results indicate that the VC-guided intervention yielded at least comparable, if not more substantial, improvements in perceived health status, particularly among participants in the VC-guided cardiological programs (as evidenced by the percentage increase from baseline and compared to the control groups).

The patients generally had positive user experiences with the virtual coaching system (see Figure 3 for an overview of the UEQ results), particularly regarding the stimulation and novelty (hedonic dimensions). However, ratings for the pragmatic dimensions (perspicuity, efficiency, and dependability) were more mixed, with some neutral or negative feedback, especially for the cardiological programs. This could be attributed to the more complex setup involving additional monitoring devices and pandemic-related delays. Patients suggested that improving technical aspects, especially device connectivity, could enhance the user experience. The effort required for technical adjustments and the reduced technology affinity among older patients may have been underestimated. Nevertheless, neurological patients reported a satisfactory user experience with no significant adverse events.

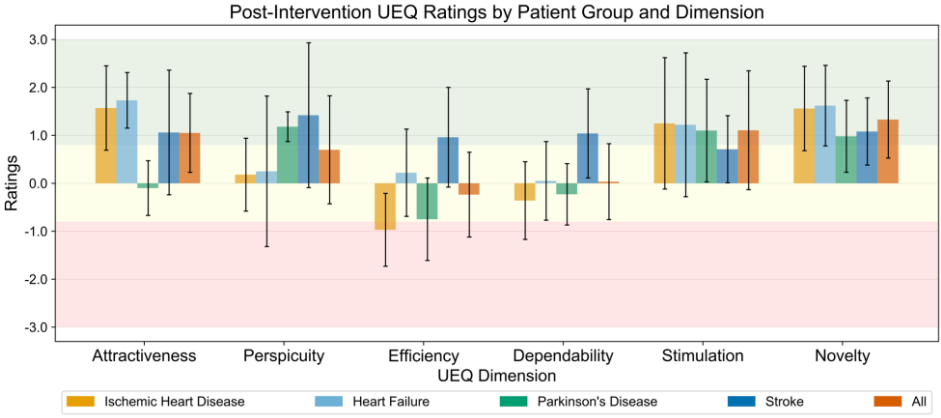

Figure 3. UEQ ratings for all patient groups after the Pilot Phase; UEQ ratings above 0.8 are considered positive evaluations (in the green diagram area following a traffic light system; from [4]).

4. Discussion

The present study demonstrates that the VC solution is potentially effective and well-accepted in clinical practice. The study fills a critical gap in evaluating virtual coaching-based IT artifacts by providing comprehensive and clinically relevant insights. Essentially, the potential advantages of the VC-based system can be shown in all measured QoL scales and the high acceptance rates in the UEQ. From a clinical perspective, the study paves the way for large-scale randomized controlled trials (RCTs), essential for the widespread adoption of VC in clinical practice. From an IT perspective, the study shows how complex digital interventions in healthcare can be sustainably designed (see the derived *Design Principles* in [4]). Also on the developer side, a multi-user interface should be considered to address both the coachee's (patient) and human coach's (health professional) needs. Standardization and interoperability are considered prerequisites and enablers for a *VC ecosystem*. The study was conducted in a complex

real-world setting, exposing it to a broader range of testing factors compared to a controlled laboratory environment, thereby challenging its relevance and rigor. Likewise, it was possible to demonstrate the generic applicability of the VC solution design for different disease contexts covering the needs of cardiological and neurological patients. This also represents a first step towards delivering VC interventions targeting multiple morbidities, as a rising issue and challenge for healthcare systems. For the future application of the VC solution, special consideration should be given to the suitability of the patients (no physical or mental limitations or sufficient affinity for the technology to be used) and the healthcare system (for example, there were no rehabilitation programs in Spain, which made the VC solution of particular advantage).

5. Conclusions

In summary, the study addresses the shortcomings of the current research in the field of VCs concerning the lack of holistic interventions, the impact of VCs in general, and the absence of practically rooted evidence by providing insights on the potential effectiveness (increase of participants' QoL due to the VC solution). Positive user experience assessments (UEQ scores thresholds) for the VC home rehabilitation were also observed. Future research should focus on home-based rehabilitation interventions facilitated by VC technologies, including remote monitoring and guidance from healthcare professionals. Large-scale clinical trials (RCTs) are needed to provide robust statistical evidence on the advantageousness of the proposed solution. The present study contributes to the evidence of VC solutions in the rehabilitation domain and the research on persuasive and sustaining digital health systems.

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References

[1] Tropea P, Schlieter H, Sterpi I, Judica E, Gand K, Caprino M, Gabilondo I, Gomez-Esteban JC, Busnatu S, Sinescu C, Kyriazakos S, Anwar S, Corbo M. Rehabilitation, the Great Absentee of Virtual Coaching in Medical Care: Scoping Review. Journal of Medical Internet Research. 2019;21(10):e12805.

[2] Tsiouris KM, Tsakanikas VD, Gatsios D, Fotiadis DI. A Review of Virtual Coaching Systems in Healthcare: Closing the Loop With Real-Time Feedback. Front Digit Health [Internet]. 2020 [cited 2021 May 12];2. Available from: https://www.frontiersin.org/articles/10.3389/fdgth.2020.567502/full

[3] Baskerville R, vom Brocke J, Mathiassen L, Scheepers H. Clinical research from information systems practice. European Journal of Information Systems. 2023 Jan 2;32(1):1–9.

[4] Schlieter H, Gand K, Weimann T, Sandner E, Kreiner K, Thoma S, Liu J, Caprino M, Corbo M, Seregni A, Tropea P, Del Pino R, Gomez-Esteban JC, Gabilondo I, Lacraru AE, Busnatu SS. Designing Virtual Coaching Solutions – Design and Evaluation of a Digital Health Intervention for Rehabilitation Care. Bus Inf Syst Eng. forthcoming;

[5] Cocks K, Torgerson DJ. Sample size calculations for pilot randomized trials: a confidence interval approach. J Clin Epidemiol. 2013 Feb;66(2):197–201.

[6] Laugwitz B, Held T, Schrepp M. Construction and Evaluation of a User Experience Questionnaire. In: Holzinger A, editor. HCI and Usability for Education and Work. Berlin, Heidelberg: Springer; 2008. p. 63–76. (Lecture Notes in Computer Science).