

# The feasibility of virtual reality therapy for upper extremity mobilization during and after ICU admission (#100303)

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# The feasibility of virtual reality therapy for upper extremity mobilization during and after ICU admission

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**Background:** Early mobilization reduces long-term muscle weakness after intensive care unit (ICU) admission, but barriers (e.g. anxiety, lack of motivation) may complicate patients' adherence to early mobilization. Virtual Reality (VR) presents immersive stimuli, which may increase motivation and adherence. This study aimed to examine the feasibility and efficacy of VR-therapy using a VR-headset during ICU- and subsequent general ward admission. Methods: **Ten adult** ICU-patients, mechanically ventilated for  $\geq 48$ h, and clinically capable, were included. VR-therapy was offered three times a week for 20 min. in addition to standard care. To train upper extremity functionality patients were instructed to complete puzzles with increasing level of difficulty. Feasibility outcomes were number and duration of VR-therapy sessions, actual training time, session efficiency, and adherence. Patients' hand-grip strength and Morton Mobility Index (MMI) were evaluated by a pre- and post-test. Results: Patients followed three VR-therapy sessions of 20 min. **per week** with 13 min. of actual training time. Session efficiency ranged from 25% to 93%. Patients adhered on average to 60% of the VR-therapy sessions. MMI scores increased significantly from pre- (26 [24-44]) to post-test (57 [41-85],  $p=0.005$ ), indicating better balance and mobility. In conclusion: VR-therapy in (former) ICU-patients is feasible during stay in the ICU and general ward.

# **The feasibility of virtual reality therapy for upper extremity mobilization during and after ICU admission**

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23 **Abstract**

24 **Background:** Early mobilization reduces long-term muscle weakness after intensive care unit  
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 26 adherence to early mobilization. Virtual Reality (VR) presents immersive stimuli, which may  
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 39 (former) ICU-patients is feasible during stay in the ICU and general ward.

# Introduction

In the Netherlands, an average of 80.000 patients are admitted to the intensive care unit (ICU) annually [1]. Reasons for an ICU-admission are diverse, including major operations, trauma and infection [2]. Advances in the management of critically ill patients have led to an increase in survival, but not necessarily to an improvement in quality of life [3,4]. Many ICU-survivors suffer from newly developed or worsened long-term mental (e.g. cognitive dysfunction, emotional distress) and physical impairments (e.g. muscle weakness, reduced endurance) as a result of ICU-treatment [4], termed Post Intensive Care Syndrome (PICS) [5]. It is estimated that 50-70% of the ICU-survivors suffer from PICS one year after ICU-admission [6,7]. The growing number of ICU-survivors with PICS shows the need to address long-term consequences more fully.

**Muscle weakness**, referred to as ICU-acquired weakness (ICU-AW), is one of the consequences of critical illness and immobilization. ICU-AW occurs within 24h and continues to progress during admission [6–8]. In the ICU, mobilization is therefore started as early as possible to diminish long-term muscle weakness. Early mobilization could include any combination of bed mobility practice, active exercises in bed, transfers from sitting to standing and walking, or lifting to a chair [6]. Early mobilization is feasible, safe, and can improve muscle strength and function at ICU-discharge [9–13]. However, in clinical practice, there are barriers to implement early mobilization, such as lack of staff, equipment, and knowledge [14]. Moreover, patient anxiety and lack of motivation, confidence, and knowledge about ICU-AW are identified as barriers impeding adherence to early mobilization [15]. The ideal early mobilization program should deliver therapy that is feasible for staff as well as safe and motivating for patients.

Virtual Reality (VR) therapy may provide a solution to address barriers of delivering early ICU mobilization in a fun, relaxed way. VR can influence patient behavior by presenting strong immersive stimuli and its ability to provide a feeling of presence and emotional engagement in a virtual three-dimensional world [16–18]. Exercises embedded in VR are more engaging than in a sterile medical setting, which may increase patient motivation and subsequent adherence to therapy [17–19]. VR is a helpful tool to recover cognitive and motor functioning of populations with neurodegenerative diseases, traumatic brain injury, and stroke [17,18,20–23].

Prior to using VR-therapy as an adjunct to standard daily early mobilization and physical therapy in ICU-patients, its feasibility must be assessed. The primary aim of this study **is** therefore to evaluate the feasibility of VR-therapy using a VR-headset during ICU- and subsequent general

ward admission. The secondary aim is to examine the effect of VR-therapy on physical recovery during ICU- and general ward admission. Based on previous evidence [24–26], we hypothesize that using a dedicated VR-game is feasible for early ICU mobilization. In addition, we expect that VR-therapy benefits physical recovery.

## Materials & Methods

### *Study design*

A healthcare innovation pilot study was performed with a pre-post design. A local medical ethics committee (Regionale Toetsingscommissie Patiëntgebonden Onderzoek, RTPO) ruled that the Medical Research Involving Humans Act (Dutch: Wet medisch-wetenschappelijk onderzoek met mensen, WMO) was not applicable, due to the non-incriminating character of the study (Regionale Toetsingscommissie Patiëntgebonden Onderzoek, Leeuwarden, The Netherlands; nWMO-number: nWMO 20210056). Nevertheless, a written informed consent procedure for data collection was deemed reasonable.

### *Population*

Patients were recruited from March 2022 through May 2022 at the ICU of the Medical Center Leeuwarden, a tertiary teaching hospital in the Netherlands. Inclusion criteria were:  $\geq 18$  years old, mechanically ventilated for  $\geq 48$ h in the ICU, and capable to participate based on clinical assessment by clinical staff. Patients were excluded in case of an active delirium, indicated by an ICU-nurse, clinician, or Confusion Assessment Method for ICU  $\geq 1$  [27], and/or if they did not understand Dutch. All patients gave written informed consent for data collection prior to participation.

### *VR-therapy*

VR-therapy was offered as a complement to standard daily physical therapy and early ICU mobilization. A VR-headset, the Oculus Quest 2<sup>®</sup> (Meta Technologies, LLC), was used for VR-therapy. To ensure VR-therapy was suitable for recovering ICU-patients, a dedicated prototype game was developed using participatory design sessions with experts from the field of serious gaming, researchers, clinicians, former ICU-patients, and their informal caregivers. The design process consisted of several brainstorm sessions, iteration scenarios testing both hardware and

software using existing rehabilitation games, in-hospital experimentation to ensure the game would be playable in the early stages of recovery and, finally, the pilot study described in this paper. These steps resulted in a VR-game in which patients were instructed to complete puzzles with increasing levels of difficulty to train upper extremity functionality (Figure 1). The puzzles were made on a table-like surface in a virtual home environment, while the hand movements were tracked by the VR-headset and displayed in the VR-environment. The visual elements in the virtual home environment were designed previously as part of an intervention for loneliness in older adults by 8D Games in collaboration with Veldmeijer et al. (2020).

*Figure 1*

# ***Protocol***

VR-therapy was offered three times a week for 20 min. in the ICU and on the post ICU hospital ward. Training started when clinical staff deemed the patient physically and mentally capable to use the VR-headset until hospital discharge or for a maximum of four weeks. A trained researcher was present during VR-therapy. The trained researcher provided the patient with a brief introduction to the software and then helped to put on the VR-headset and to select the level of difficulty, the number of puzzle pieces, and the use of left and/or right hand. Patients could perform VR-therapy in a seated position in bed or a chair.

# ***Outcomes***

Primary feasibility outcomes were the number and duration of VR-therapy sessions, actual time spent using the VR-game, session efficiency (the actual time spent using the VR-game/duration of VR-therapy session\*100%), and adherence to VR-therapy. Feasibility outcomes were presented per patient and per VR-therapy session to explore changes over time. During each session, the number and nature of adverse events (e.g. dizziness, pain) were monitored as well as fatigue and satisfaction level using the Borg Rating of Perceived Exertion Scale (Borg-RPE) (6-20) and Visual Analogue Scale (VAS) (0-100), respectively. The BORG-RPE was used in agreement with the author according to the Royal Dutch Fellowship for Physical Therapy (KNGF) guidelines for cardiac rehabilitation [28]. Additionally, patients' self-reported probability of using the VR-game in a home situation using a VAS (0-100), hand-grip strength by a handheld dynamometer [29], and the MMI [30] were evaluated by a pre- and post-test. MMI consists of 15 mobility items (bed, chair, static balance, walking, and dynamic balance items) and ranges from 0 to 100, whereas 0 represents poor mobility and 100 independent mobility [30].

# ***Statistical analyses***

Quantitative data were presented as categorical and continuous variables and qualitative data from patient and trainer experiences were described as in-text quotes. Descriptive statistics were used to obtain a detailed picture of the data. Wilcoxon signed-rank tests were used to assess differences in self-reported probability of using VR-game in a home situation, MMI, and hand-grip strength between pre- and post-test data. Analyses were conducted using SPSS Statistics 24 software (IBM, Irvine, CA, USA) with  $p < 0.05$  considered to be statistically significant.

# Results

Of 12 eligible patients, ten patients gave permission to participate in this study. Nine patients completed the training. Patient characteristics are shown in Table 1. Four out of ten patients were diagnosed with comorbidities prior to ICU-admission; of those patients three had been diagnosed with chronic obstructive pulmonary disease and one with diabetes type 2.

Clinical staff deemed patients capable to use the VR-headset after a median of five days of ICU-admission. Patients participated in three VR-therapy sessions per week with a median session duration of 20 min. and actual VR-gaming time ranging from 3 to 22 min. (Table 2). The remaining session time was used for preparation, giving the patient an introduction to the software, helping the patient to put on the VR-headset, selecting the game settings, resting if needed, interruption by other healthcare providers, and/or restarting VR-headset in case of technical difficulties. This resulted in session efficiencies ranging from 25% to 93%. To illustrate, patients 3 and 10 were very weak and therefore needed more support with the VR headset and could only sustain VR-therapy for a short time resulting in low session efficiencies. On the other hand, patient 7 really liked VR-therapy and therefore trained with extremely light to very light activity levels to last longer. Patients rated a **satisfaction** and fatigue level of 80/100 and 11/20, respectively. Reasons for non-adherence to VR-therapy were: tiredness (4 (11%)), patient was unable to sit up properly (1 (3%)), no motivation (4 (11%)), patient saw no added value of VR-therapy (6 (17%)), or hand-tracking difficulties (1 (3%)).

No serious adverse events were experienced by patients or observed by trained researchers. Two patients experienced pain due to fractured ribs and sternum and were unable to play a higher level. Another patient reported some dizziness after VR-therapy. In general, patients experienced VR-therapy sessions as a “fun activity”, “special experience”, and “fun and at the same time effective activity during the long hospital days”. With more consecutive VR-therapy sessions, the session duration, VR-gaming duration, session efficiency, satisfaction level, and fatigue level increased, whereas adherence decreased (Table 3).

The median self-reported probability of using the VR-game in a home situation increased from pre- to post-test, but not significantly (Table 4). MMI scores significantly increased over time ( $p=0.005$ ), indicating better balance and mobility (Figure 2A). No significant differences in absolute and relative hand-grip strengths (Figure 2B) were found between pre- and post-test. We

174 refer to Appendix A for data on individual differences in hand-grip strength between pre- and post-  
 175 test.

176

177 *Figure 2*

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# Discussion

In this study, we aimed to evaluate the feasibility and efficacy of VR-therapy using a VR-headset during ICU- and subsequent general ward admission. We showed that it was feasible to offer VR-therapy three times a week for 20 min. in addition to standard daily physical therapy and early mobilization to train upper extremity functionality in patients with critical illness. Ten out of twelve eligible patients gave consent to participate in this study, potentially showing patients' curiosity to VR-therapy. Overall, clinical staff deemed patients clinically capable to start VR-therapy at day five of ICU-admission. Most patients (80%) showed moderate to high adherence to VR-therapy. No serious adverse events were reported or experienced by patients or trained researchers. Patients rated a high satisfaction level and were not extremely fatigued after VR-therapy.

VR-therapy in ICU-patients is feasible when having a seated position in bed or chair as underlined by previous evidence [24,26]. Norouzi-Gheidari et al. [25] concluded that VR-therapy was feasible in stroke patients with a session efficiency of 49%, which is comparable to our session efficiency of 57%. However, our predetermined goal to train 20 min. was generally not achieved. We observed that VR-therapy using our prototype VR-game was too exhausting for some patients. Moreover, fatigue led to non-adherence to VR-therapy. Fatigue has been shown to be a reason for activity cessation and a barrier to adhere to exercise in ICU-patients by others as well [14,24,33]. On the other hand, VR-therapy was not challenging enough to stay motivated for 20 min. for other patients. The challenge of VR-therapy should match the skills of patients to make them enjoy and endure VR-therapy [34], which should be considered in the further development of VR-therapy. This may also increase adherence on long-term, as adherence decreased with more consecutive VR-therapy sessions in the current study.

Patients reported fatigue levels of 7/20 to 13/20 after VR-therapy, indicating that our VR-therapy led to very light to somewhat hard activity levels. Training intensities corresponding to a Borg-RPE range 11–13 are recommended in sedentary, less fit, and untrained individuals, as well as patients with cardiovascular diseases [28]. This suggests that our VR-therapy met the recommended training intensities for most ICU-patients. For patients who scored lower on the BORG, more advanced levels may be needed to achieve adequate training intensity.

Overall, ICU-patients significantly improved their balance and mobility from baseline to hospital discharge. We found a better mobility score than previous studies observed in ICU-

patients receiving conventional therapy at ICU-discharge [30,35], but comparable to mobility scores measured at hospital discharge [36]. Moreover, our ICU-patients' hand-grip strength was comparable to hand-grip strengths after standard care at hospital discharge [13]. However, Beumeler et al. [37] not only found a lower hand-grip strength, but also a poorer mobility score at ICU-discharge in ICU-survivors of the same ICU-department as our study. This may indicate that VR-therapy resulted in better recovery of muscle strength and mobility. However, it is of note that patients in this study received VR-therapy in addition to standard daily early mobilization and physical therapy, which have been associated with improvement in muscle strength and function as well [11–13].

In general, patients were satisfied with VR-therapy. In line with this, complementing care with applications of eHealth, serious gaming, and remote care may ensure continuity in rehabilitation. Our results show that the self-reported probability of using the VR-game at home increased from baseline to hospital discharge. In stroke patients, adherence to a home-based VR-therapy is good [38] and the efficacy seems comparable with clinic-based VR-therapy [39].

The present findings are important for ICU-patients, because physical activity has shown benefit in preventing PICS [11–13]. This is the first study evaluating the feasibility of using a dedicated VR-game for early ICU mobilisation. Our prototype VR-game provided individualised therapy as we were able to set the level of difficulty, number of puzzle pieces, and use of left and/or right hand. The high satisfaction rate indicates that individualised VR-therapy may be successful in treatment of the heterogeneous ICU-population. In addition, the VR-headset provides detailed rotational and positional data of the head and hands over time [40], which may help to optimise and individualise VR-therapy. However, processing of these data was beyond the scope of this paper.

Despite the promising results of this study, there are some limitations to take into consideration. As a pilot feasibility study, our study design did not include a control group. We therefore cannot comment on the efficacy on physical recovery of VR-therapy when compared to standard daily early mobilization and physical therapy. In addition, the small sample size limited the ability to detect clinically relevant differences. However, in this high-risk population it was important to prove first that VR-therapy using a VR-headset is feasible and without significant adverse events before proceeding into larger trials.

## Conclusion

In conclusion, VR-therapy using our prototype VR-game to train upper extremity functionality is feasible in the ICU and on the post ICU hospital ward and is associated with an improvement in physical recovery in ICU-patients. Future studies should examine whether VR-therapy as a complement to conventional therapy improves muscle strength and function using larger sample sizes and randomized controlled trials. Furthermore, studies with long-term follow-up are needed to determine the extent to which gains in muscle strength and function are preserved and whether VR-therapy at home would be valuable to maintain and/or increase gains.

## Acknowledgement

The authors would like to thank all patients, informal caretakers, and healthcare professionals for participating in the various steps of the user-centered design process. We are grateful to 8D Games for facilitating this process, developing the VR-game, and providing continuous technical assistance.

## Data availability statement

The data that support the findings of this study are available from the corresponding author, LFEB, upon reasonable request.

## Declaration of interest statement

The authors report no conflict of interest. The research team collaborated with 8D Games for the development of the VR-game. Development costs were covered by a dedicated innovation fund of the Medical Centre Leeuwarden. VR-headsets were acquired by the Intensive Care Unit of the Medical Centre Leeuwarden. The company had no role in the formulation of the study protocol, study execution, or analysis and processing of the data.

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377 **Appendix**

378 ***Appendix A***

379 Individual differences in hand-grip strength between pre- and post-test.

380 *Figure 3*

381

382 ***Appendix B***

383 Raw data baseline and post-test (Table 5a) and training characteristics (Table 5b)

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386

# **Figure captions**

Figure 1: Screenshot from VR-game. A) One of the bubbles lights up; B) By touching a bubble, it bursts, and the puzzle piece falls on the table; C) Patients navigate their hand to a fallen puzzle piece; D) Patients can flip puzzle pieces by turning their hand over and put down a puzzle piece by moving their hand down towards the table.

Figure 2: Individual differences between pre- and post-test. A) MMI score; B) Relative hand-grip strength of right hand. Abbreviations: MMI=the Morton Mobility Index.

Figure 3: Individual differences between pre- and post-test. A) Absolute hand-grip strength of right hand; B) Absolute hand-grip strength of left hand; C) Relative hand-grip strength of left hand.

# Table 1 (on next page)

Table 1: Patient characteristics

Data are presented as median [IQR] or number (%). Abbreviations: ICU=Intensive Care Unit; APACHE=Acute Physiology and Chronic Health Evaluation . Notes: <sup>a</sup> Ranges from 0 to 299, with higher values representing a worse prognosis [31]. <sup>b</sup> Ranges from 1 (very fit) to 9 (terminally ill) [32]. <sup>c</sup> Missing for five patients.

**Table 1: Patient characteristics**

|                                                     | <b>ICU-patients (n=10)</b> |
|-----------------------------------------------------|----------------------------|
| <b>Age (years)</b>                                  | 71 [63-79]                 |
| <b>Male</b>                                         | 7 (70%)                    |
| <b>BMI (kg/m<sup>2</sup>)</b>                       | 27.1 [22.5-29.6]           |
| <b>APACHE-III score<sup>a</sup></b>                 | 74 [66-104]                |
| <b>Frailty score<sup>b,c</sup></b>                  | 2 [2-3]                    |
| <b>Admission type</b>                               |                            |
| Medical                                             | 6 (60%)                    |
| Elective surgery                                    | 1 (10%)                    |
| Acute surgery                                       | 3 (30%)                    |
| <b>Cardiopulmonary resuscitation</b>                | 3 (30%)                    |
| <b>Sepsis</b>                                       | 1 (10%)                    |
| <b>Medical comorbidities</b>                        | 4 (40%)                    |
| <b>Length of stay ICU prior to inclusion (days)</b> | 5 [4-10]                   |
| <b>Length of stay ICU (days)</b>                    | 6 [4-9]                    |
| <b>Length of stay hospital (days)</b>               | 12 [10-19]                 |
| <b>Mechanical ventilation (days)</b>                | 3 [3-7]                    |

Data are presented as median [IQR] or number (%). Abbreviations: ICU=Intensive Care Unit; APACHE=Acute Physiology and Chronic Health Evaluation .

Notes:

<sup>a</sup> Ranges from 0 to 299, with higher values representing a worse prognosis [31].

<sup>b</sup> Ranges from 1 (very fit) to 9 (terminally ill) [32].

<sup>c</sup> Missing for five patients.

# Table 2 (on next page)

Table 2: Summary of feasibility outcome measures per patient.

Data are presented as median (min.-max.). Abbreviations: Adh=Adherence; ID=patient identification; VR=virtual reality; VAS=visual analogue scale; Borg-RPE=Borg Rating of Perceived Exertion scale. Notes: a Ranging from 0 to 100. b Ranging from 6 to 20. c Patient 5 was too tired and short of breath to participate in VR-therapy sessions. d Missing for one VR-therapy session.

Table 2: Summary of feasibility outcome measures per patient.

| ID             | Nr of research visits | Nr of sessions completed | VR-therapy session duration (min.) | VR-gaming duration (min.) | Session efficiency (%)  | Satisfaction level (VAS) <sup>a</sup> | Fatigue level (Borg-RPE) <sup>b</sup> | Adh. (%) |
|----------------|-----------------------|--------------------------|------------------------------------|---------------------------|-------------------------|---------------------------------------|---------------------------------------|----------|
| 1              | 4                     | 3                        | 25 (20-26)                         | 19 (19-19)                | 74 (71-93)              | 90 (75-100)                           | 13 (13-13)                            | 75       |
| 2              | 3                     | 2                        | 20 (9-31)                          | 8 (6-9) <sup>c</sup>      | 49 (28-71)              | 75 (60-90)                            | 11 (10-11)                            | 67       |
| 3              | 2                     | 1                        | 10 (10-10)                         | 3 (3-3)                   | 25 (25-25)              | 75 (75-75)                            | 13 (13-13)                            | 50       |
| 4              | 3                     | 2                        | 33 (32-33)                         | 17 (15-19)                | 52 (48-57)              | 85 (70-100)                           | 11 (11-11)                            | 67       |
| 5 <sup>c</sup> | 3                     | 0                        | -                                  | -                         | -                       | -                                     | -                                     | 0        |
| 6              | 3                     | 3                        | 20 (15-20)                         | 7 (6-7) <sup>d</sup>      | 39 (35-43) <sup>d</sup> | 80 (80-100)                           | 11 (9-11)                             | 100      |
| 7              | 3                     | 3                        | 32 (25-40)                         | 18 (15-22)                | 69 (37-73)              | 90 (80-90)                            | 9 (7-9)                               | 100      |
| 8              | 3                     | 2                        | 19 (18-20)                         | 11 (10-13)                | 59 (53-65)              | 63 (50-75)                            | 11 (9-13)                             | 67       |
| 9              | 5                     | 3                        | 20 (12-30)                         | 10 (8-17)                 | 64 (34-83)              | 80 (70-100)                           | 7 (7-11)                              | 60       |
| 10             | 7                     | 1                        | 20 (20-20)                         | 7 (7-7)                   | 33 (33-33)              | 75 (75-75)                            | 13 (13-13)                            | 14       |
| All subjects   |                       |                          | 20 (9-40)                          | 13 (3-22)                 | 57 (25-93)              | 80 (50-100)                           | 11 (7-13)                             | 60       |

Data are presented as median (min.-max.). Abbreviations: Adh=Adherence; ID=patient identification; VR=virtual reality; VAS=visual analogue scale; Borg-RPE=Borg Rating of Perceived Exertion scale.

Notes:

<sup>a</sup> Ranging from 0 to 100.

<sup>b</sup> Ranging from 6 to 20.

<sup>c</sup> Patient 5 was too tired and short of breath to participate in VR-therapy sessions.

<sup>d</sup> Missing for one VR-therapy session.

# Table 3(on next page)

Table 3: Summary of feasibility outcome measures per VR-therapy session.

Data are presented as median (min.-max.). Abbreviations: VR=virtual reality; VAS=visual analogue scale; Borg-RPE=Borg Rating of Perceived Exertion scale. Notes: a Ranging from 0 to100. b Ranging from 6 to 20. c Missing for one patient.

**Table 3: Summary of feasibility outcome measures per VR-therapy session.**

| <b>VR-therapy session</b> | <b>VR-therapy session duration (min.)</b> | <b>VR-gaming duration (min.)</b> | <b>Session efficiency (%)</b> | <b>Satisfaction level (VAS)<sup>a</sup></b> | <b>Fatigue (Borg-RPE)<sup>b</sup></b> | <b>Adherence (%)</b> |
|---------------------------|-------------------------------------------|----------------------------------|-------------------------------|---------------------------------------------|---------------------------------------|----------------------|
| 1                         | 20 (9-32)                                 | 8 (3-18)                         | 45 (25-73)                    | 78 (50-100)                                 | 11 (7-13)                             | 80                   |
| 2                         | 26 (18-33)                                | 18 (9-22) <sup>c</sup>           | 63 (28-83) <sup>c</sup>       | 80 (70-90)                                  | 11 (9-13)                             | 70                   |
| 3                         | 20 (12-40)                                | 11 (7-19)                        | 50 (35-93)                    | 85 (70-90)                                  | 9 (7-13)                              | 33                   |
| 4                         | 25 (25-25)                                | 19 (19-19)                       | 74 (74-74)                    | 100 (100-100)                               | 13(13-13)                             | 33                   |

Data are presented as median (min.-max.). Abbreviations: VR=virtual reality; VAS=visual analogue scale; Borg-RPE=Borg Rating of Perceived Exertion scale.

Notes:

<sup>a</sup> Ranging from 0 to100.

<sup>b</sup> Ranging from 6 to 20.

<sup>c</sup> Missing for one patient.

# Table 4(on next page)

Table 4: Difference of probability of using game in home situation, hand-grip strength, and MMI between pre- and post-test.

Data are presented as median [IQR]. Abbreviations: ICU=Intensive Care Unit; VAS=visual analogue scale; MMI=the Morton Mobility Index. \*Significantly different ( $p<0.05$ ) with Wilcoxon signed rank test. Notes: aMissing for one patient. bThe right hand was dominant for nine patients and the left hand for one patient.

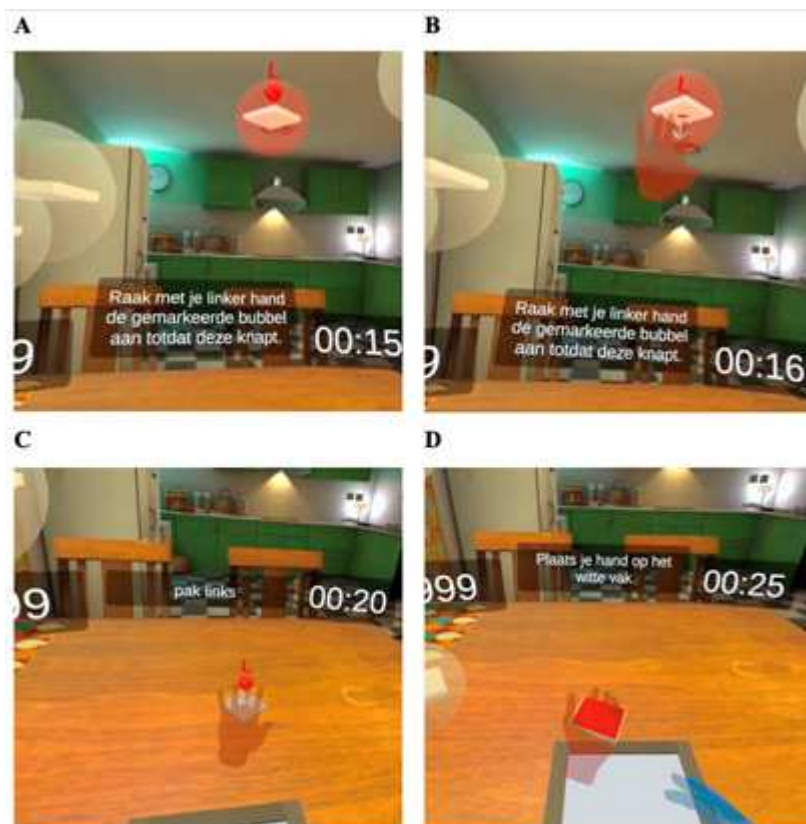
**Table 4: Difference of probability of using game in home situation, hand-grip strength, and MMI between pre- and post-test.**

|                                                                                                                                                                                                         | Baseline (ICU)    | Post-test (ICU/general ward) | p-value |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------|---------|
| <b>VAS-score</b>                                                                                                                                                                                        |                   |                              |         |
| Probability of using game in home situation                                                                                                                                                             | 45 [28-70]        | 78 [26-88] <sup>a</sup>      | 0.066   |
| <b>MMI</b>                                                                                                                                                                                              | 26 [24-44]        | 57 [41-85]                   | 0.005*  |
| <b>Absolute hand-grip strength<sup>b</sup></b>                                                                                                                                                          |                   |                              |         |
| Right hand (kg)                                                                                                                                                                                         | 23.8 [11.9-35.4]  | 31.0 [12.7-39.5]             | 0.386   |
| Left hand (kg)                                                                                                                                                                                          | 25.2 [10.5-29.1]  | 25.2 [17.3-34.6]             | 0.386   |
| <b>Relative hand-grip strength<sup>c</sup></b>                                                                                                                                                          |                   |                              |         |
| Right hand (%)                                                                                                                                                                                          | 70.0 [52.2-91.6]  | 88.8 [50.4-106]              | 0.114   |
| Left hand (%)                                                                                                                                                                                           | 74.3 [56.7-105.6] | 92.8 [70.0-121]              | 0.074   |
| Data are presented as median [IQR]. Abbreviations: ICU=Intensive Care Unit; VAS=visual analogue scale; MMI=the Morton Mobility Index. *Significantly different (p<0.05) with Wilcoxon signed rank test. |                   |                              |         |
| Notes:                                                                                                                                                                                                  |                   |                              |         |
| <sup>a</sup> Missing for one patient.                                                                                                                                                                   |                   |                              |         |
| <sup>b</sup> The right hand was dominant for nine patients and the left hand for one patient.                                                                                                           |                   |                              |         |

# Figure 1

Screenshot from VR-game.

A) One of the bubbles lights up; B) By touching a bubble, it bursts, and the puzzle piece falls on the table; C) Patients navigate their hand to a fallen puzzle piece; D) Patients can flip puzzle pieces by turning their hand over and put down a puzzle piece by moving their hand down towards the table.



# Figure 2

Figure 2: Individual differences between pre- and post-test. A) MMI score; B) Relative hand-grip strength of right hand. Abbreviations: MMI=the Morton Mobility Index.

