Disability and Rehabilitation

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/idre20

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To cite this article: Nathalie Swinnen, Eling D. de Bruin, Vânia Guimarães, Chantal Dumoulin, Jacqueline De Jong, Riekje Akkerman, Mathieu Vandenbulcke, Brendon Stubbs & Davy Vancampfort (2023): The feasibility of a stepping exergame prototype for older adults with major neurocognitive disorder residing in a long-term care facility: a mixed methods pilot study, Disability and Rehabilitation, DOI: 10.1080/09638288.2023.2182916

To link to this article: https://doi.org/10.1080/09638288.2023.2182916

DISABILITY AND REHABILITATION
https://doi.org/10.1080/09638288.2023.2182916

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ORIGINAL ARTICLE

The feasibility of a stepping exergame prototype for older adults with major neurocognitive disorder residing in a long-term care facility: a mixed methods pilot study

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ABSTRACT

Purpose: To explore the feasibility of an exergame prototype in residential individuals with major neurocognitive disorder (MNCD).

Materials and methods: Participants were randomly assigned to a 12-week stepping exergame training or traditional exercise (active control group). Semi-structured interviews were conducted after six and 12 weeks of exergaming. Qualitative data were thematically analysed using NVivo 12. The Short Physical Performance Battery, one minute sit-to-stand test, Mini-Mental State Examination (MMSE), Neuropsychiatric Inventory, Cornell Scale for Depression in Dementia, and Dementia Quality of Life were assessed at baseline and post intervention using a Quade's ANCOVA.

Results: Seven older adults with MNCD in the exergame and 11 in the active control group completed the study [mean age = 83.2 ± 6.5 years; 94.4% female; SPPB score = 7.3 ± 2.4]. Results indicated that the VITAAL exergame prototype was experienced as enjoyable and beneficial. The post-MMSE score was higher (η^2=.02, p = 0.01, F = 8.1) following exergaming versus traditional exercise.

Conclusions: The findings suggest that the exergame prototype is accepted by individuals with MNCD residing in a long-term care facility when they are able to participate and under the condition that they are extensively guided. The preliminary efficacy results revealed higher post-MMSE scores after exergaming versus traditional exercise. Future trials should confirm or refute these findings.

Trial registration: The trial was registered in ClinicalTrials.gov (Identifier: NCT04436315)

ARTICLE HISTORY
Received 8 June 2022
Revised 13 February 2023
Accepted 16 February 2023

KEYWORDS
Cognition; dementia; exercise; long-term care; physical activity; qualitative research; serious game

➤ IMPLICATIONS FOR REHABILITATION

- The VITAAL exergame prototype is accepted by individuals with MNCD residing in a long-term care facility who are able to participate.
- Supervision of exergaming by health professionals is essential for successful implementation.
- The VITAAL exergame prototype might maintain cognitive levels in major neurocognitive disorder longer than walking combined with standardised squatting and stepping exercises.

Introduction

Global population aging is associated with an increased number of older adults with major neurocognitive disorder (MNCD) [1]. MNCD is a clinical syndrome resulting in cognitive function impairments, motor decline, psychological difficulties, impairment in activities of daily living, and behavioural problems [2]. MNCD is associated with slow gait speed [3], increased risk of falling [4], and related disability [5]. The progressive functional decline in people with MNCD contributes to reduced quality of life and increased caregiver burden [6]. Consequently, many people with MNCD are transferred to long-term care facilities [6]. The interest in the prevention of problems that cause morbidity and mortality and in optimising the quality of life is increasing. At present, the primary goals for institutionalised people with MNCD are maintaining or improving their physical condition and quality of life. Non-pharmacological therapies including environment adaptation [7] and physical activity [8] are recommended and aspire to improve health and well-being [9]. It is well known that physical activity improves strength, endurance, balance, gait stability, gait speed, and overall wellbeing in older adults with MNCD [8,10,11].

Despite these advantages, engaging people with MNCD to be physically active is challenging and little is known about the optimal

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/09638288.2023.2182916.
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way to deliver it in long-term care. A reason for this could be the presence of behavioural symptoms like agitation and passivity, which are exhibited by 90% of residential individuals with MNCD [12]. Also, disorientation and decreased interest further demotivates them to be physically active [13]. Motor-cognitive training has been suggested as an intervention option. It combines cognitive training with a physical task, e.g. cognitive and balance exercises. Experiences of fun and leisure can be added, which increases training motivation and program adherence in individuals residing in long-term care facilities [14]. Combined motor-cognitive training might slow down physical and cognitive decline and even reduce or prevent falls [15–17]. Recent improvements in technology have generated means to offer combined motor-cognitive training. Exergames for example, which are videogames directed with physical movements, present an easy tool for combining cognitive and motor tasks in an enjoyable and motivating setting [18,19]. Researchers stated that stepping exergame training improves mobility, balance, gait speed, cognitive functioning, and reduces apathy and fear of falling in older adults with MNCD [20–22]. Physical interventions in this population are characterised with low adherence rates and it has been suggested that exergames could overcome this problem [8, 23]. Previous research has indicated that stepping exergame training is feasible and engaging in residential older adults with MNCD [24]. It requires participants to perform foot tapping movements from a standing position, which directly addresses gait and balance [25]. Currently, portable and affordable stepping exergames designed for older adults are however still lacking. In order to address this, an international research group developed a solution for geriatric rehabilitation [26]. This project, entitled VITAAL, was launched in May 2018 and is funded by the European Commission as a part of the Active Assisted Living Program [27]. The VITAAL multicomponent stepping exergame prototype consists of a web-based interface that allows a direct follow-up and data processing by healthcare professionals. The system aims to provide evidence-based motor-cognitive training for older adults with high usability and easy setup in the clinic and at home. The system consists of a television screen and two wearable sensors that are attached to the feet of the player. The usability of the VITAAL exergame prototype has previously been evaluated as positive by residential older adults with MNCD after completing one try-out session [28]. Feasibility and efficacy studies are recommended as next steps to examine the practicalities of program implementation [29]. Developing a feasible and efficacious exergame program is important for program sustainability, affordability, and future implementation of the program in daily clinical practice. Therefore, the aim of this study was to investigate the feasibility and preliminary efficacy of a 12-week exergame program in older adults with MNCD residing in a long-term care facility. The experiences and preliminary health outcomes of the VITAAL exergame program compared to traditional physical training, both added to care as usual, were examined in older adults with MNCD residing in a long-term care facility.

In order to address the feasibility with regards to the VITAAL multicomponent stepping exergame, this study adopted a mixed methods design combining (1) semi-structured interviews; (2) activity logs, and (3) health assessments in institutionalised older adults with MNCD.

The combination of qualitative and quantitative data was intended to obtain a full picture of the use of the VITAAL exergame prototype in older adults with MNCD residing in a long-term care facility.

Methods

Design

A feasibility study was conducted focusing on acceptability, demand, implementation, practicality, and preliminary efficacy aspects, as proposed by Bowen [29]. A brief description of these aspects can be found in Table 1. To this end, a mixed methods design was applied, which followed the Consolidated Standards of Reporting Trials guidelines (CONSORT) for quantitative research [30–32]. The Consolidated criteria for reporting qualitative research (COREQ) framework was implemented as well [33]. The trial was registered in ClinicalTrials.gov (Identifier: NCT04436315).

Participants and procedure

Over a period of 10 months (April 2021 – March 2022), all residents with MNCD of long-term care facility de Wingerd in Leuven, Belgium, were screened for inclusion. Diagnoses were made by the treating psychiatrist and possible diagnoses eligible for inclusion were vascular dementia, Alzheimer's disease, mixed dementia, Parkinson's disease, or Lewy body disease, and unspecified MNCD, conforming to the criteria of the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM 5) [34]. Additional inclusion criteria were

age $\geq$ 60 years, capacity to consent to take part in the study, visual acuity with correction sufficient to see images on a television screen, having been residing at least two weeks in the care facility at the time of inclusion, in order to limit the burden on the new residents of the long-term care facility, and to give them time to adapt to their new living situation, and the mobility requirements to perform stepping movements from an upright standing position. Individuals manifesting one or more of the following criteria were excluded from the study: any unstable health condition which, according to the American College of Sports Medicine Standards, might lead to unsafe participation [35], and mobility impairments that, according to the treating physician, prevented exergaming or exercising in an upright standing position. Participants were randomly assigned by an independent statistician using a random number generator (https://www.random.org/) to twelve weeks, three times per week 30 min of stepping exergaming added to care as usual (experimental group), or traditional physical exercise, at a same volume, added to care as usual (active control group). Care as usual consisted of pharmacotherapy, occupational activities, and physical therapy focusing on comfort care. Participants from the exergame intervention completed a semi-structured interview after six and 12 weeks of exergaming. During system use, the facilitator took handwritten field notes to record safety concerns, additional verbal instructions, required physical support, and participant comments during exergaming. Participants were monitored for adverse effects throughout the intervention. Preliminary efficacy of the VITAAL exergame prototype was evaluated through examination of group changes in outcome measures versus traditional exercise. All participants were assessed at baseline (pre-test), and after twelve weeks (post-test) by a physical therapist using the Short Physical Performance Battery (SPPB) and the one-minute sit-to-stand test [36] in order to assess mobility [37,38], the Mini-Mental State Examination [39,40], the neuropsychiatric inventory (NPI) [41], the Cornell Scale for Depression in Dementia [42], and the Dementia Quality of Life (DQoL) questionnaire [43,44]. The Montreal Cognitive Assessment (MoCA) was not repeated since participants experienced difficulties in understanding and executing the MoCA subtests when performing the assessment at baseline. The sampling was consecutive, and participants were included until no new information emerged from the interviews and data saturation was reached. The facilitator was the same person as the interviewer, and they were not blinded to intervention. It was also not possible to blind the participants for intervention allocation.

Table 1. Five key domains of an evidence-based framework for feasibility studies, from Bowen et al. [29].

Area of focus	Description	Sample outcomes of interest
Acceptability	To what extent is the VITAAL exergame program judged as suitable, satisfying, or attractive to program deliverers and to program recipients?	Satisfaction Intent to continue use Perceived appropriateness Fit within organisational culture Perceived positive or negative effects on organisation
Demand	To what extent is the VITAAL exergame program likely to be used (i.e., how much demand is likely to exist?)	Actual use Expressed interest or intention to use Perceived demand
Implementation	To what extent can the VITAAL exergame program be successfully delivered to intended participants in a defined context as planned and proposed in a pilot study?	Degree of execution Success or failure of execution Amount, type of resources needed to implement Factors affecting implementation ease or difficulty
Practicality	To what extent can the VITAAL exergame program be carried out with intended participants using existing means, resources, and circumstances and without outside intervention? Were there any adverse effects on participants?	Efficiency, speed, or quality of implementation Positive and negative effects on participants Participants' ability to carry out the intervention Cost analysis
Preliminary efficacy	Does the VITAAL exergame program show promise of being successful with the intended population, even in a highly controlled setting? Pilot data regarding the extent to which the program generates positive changes in physical, cognitive, and mental health, and changes in participation.	Intended effects of program on key variables Effect-size estimation Maintenance of changes from initial change

Ethics

The study protocol was approved by the Medical Ethics committee of UZ Leuven (reference number S64592). All residents and their caregivers were fully informed prior to participation and signed an informed consent form according to the Declaration of Helsinki before inclusion. No compensation was granted to the participants.

VITAAL exergame prototype

The VITAAL exergame prototype, an innovative system for rehabilitation and treatment in geriatric healthcare, was applied. Strength, balance, and cognitive training were performed on the exergame device [26]. The strength training consisted of a combination of classical strength exercises and Tai Chi-inspired movements. Here, a large load was placed on the muscles of the lower extremities since Tai Chi is mainly performed in a semi-squat posture. Balance training consisted of stepping movements of both feet, as the execution of rapid and correctly directed steps is effective in preventing falls [45–47]. When combined with cognitively challenging game tasks, these exercises provided a holistic training requiring simultaneous motor-cognitive interaction and mental engagement [48,49]. The VITAAL exergame explicitly targeted specific attentional and executive functions that are important for safe gait [50–54]. The system was designed to be applied effortlessly with limited technical equipment and knowledge in long-term care facilities or other settings such as hospitals. The games are web-based and designed to run anywhere there is a device that can be connected with a screen (e.g., laptop connected with a television screen) and both Bluetooth and internet connection available. The system is backed by a main server supporting the whole service and data storage, a web portal (with information about interventions, sessions, results per session, or results over a specific period), and two wearable inertial sensors to process the stepping movements and handle the game navigation. The two inertial sensors were attached to the shoes of the participant with Velcro tape. The sensors perceived accelerations and angular rotations caused by stepping movements and communicated these *via* Bluetooth with the software running on the web-enabled device. Participants played every minigame that was available in this prototype. There were two minigames focusing on strength training through the performance of wide and narrow squats, inspired by Tai Chi (nature), four minigames focusing on balance training (falling books, music, labyrinth, and mommy chicken), two minigames focusing on cognitive training (healthy food and pizza), a minigame focusing on task switching (shopping), and a minigame focusing on short-term memory training (shopping list). The design and development of these VITAAL minigames considered inputs from older adults in the investigation phase of the project [27], from the feedback obtained in a previous study [55], and from a multidisciplinary team including movement scientists, clinicians, and game designers. It was agreed that an exergame based on the execution of multidirectional steps would fit the needs of older adults the best. The participants were always guided by a physical therapist in order to facilitate safety. A picture of the system set-up is included in Figure 1 and a description of the minigames is included in Figure 2.

Exergame intervention

Participants performed three individual sessions per week for a period of 12 weeks, resulting in a total of maximum 36 sessions. Each session consisted of a walk to the exercise room (approximately five minutes), 30 min of exergaming and a walk back to the ward. The duration of exergame sessions in previous research varied from 10 min [56,57] up to 60 min [58]. In a previous study, which examined the usability of the VITAAL exergame prototype, participants stated that 30 min of exergaming was physically not too demanding [28]. It was therefore concluded that a duration of 30 min was feasible for this specific population. The VITAAL exergame prototype device was used. The starting position was an upright stance and participants interacted with the game interface by performing a stepping movement of one foot in one of the four directions: up, down, left, and right. When the game required the player to perform a step to the left or right, the associated lower limb was used. For a step in the two other directions, the player chose the lower limb of preference. The minigames provided real-time visual and auditory cues and feedback to enrich the game experience. The sessions consisted of multiple

Figure 1. Game setup.

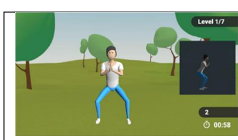	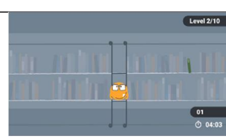	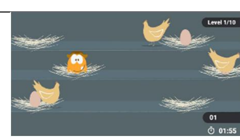	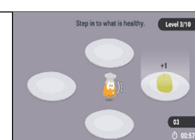	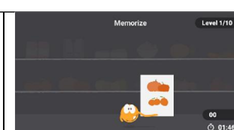
Outdoor	**Library**	**Mommy chicken**	**Healthy snacks**	**Shopping list**
Tai Chi-inspired strength training	Balance training	Balance training	Cognitive training	Short-term memory
Player imitates movements of an avatar instructor	Player avoids books from falling through multidirectional stepping	Player collects eggs while avoiding mommy chicken	Player points out healthy food and avoids unhealthy food	Player indicates whether the shown items correspond to the previously memorized shopping list

Figure 2. Game description.

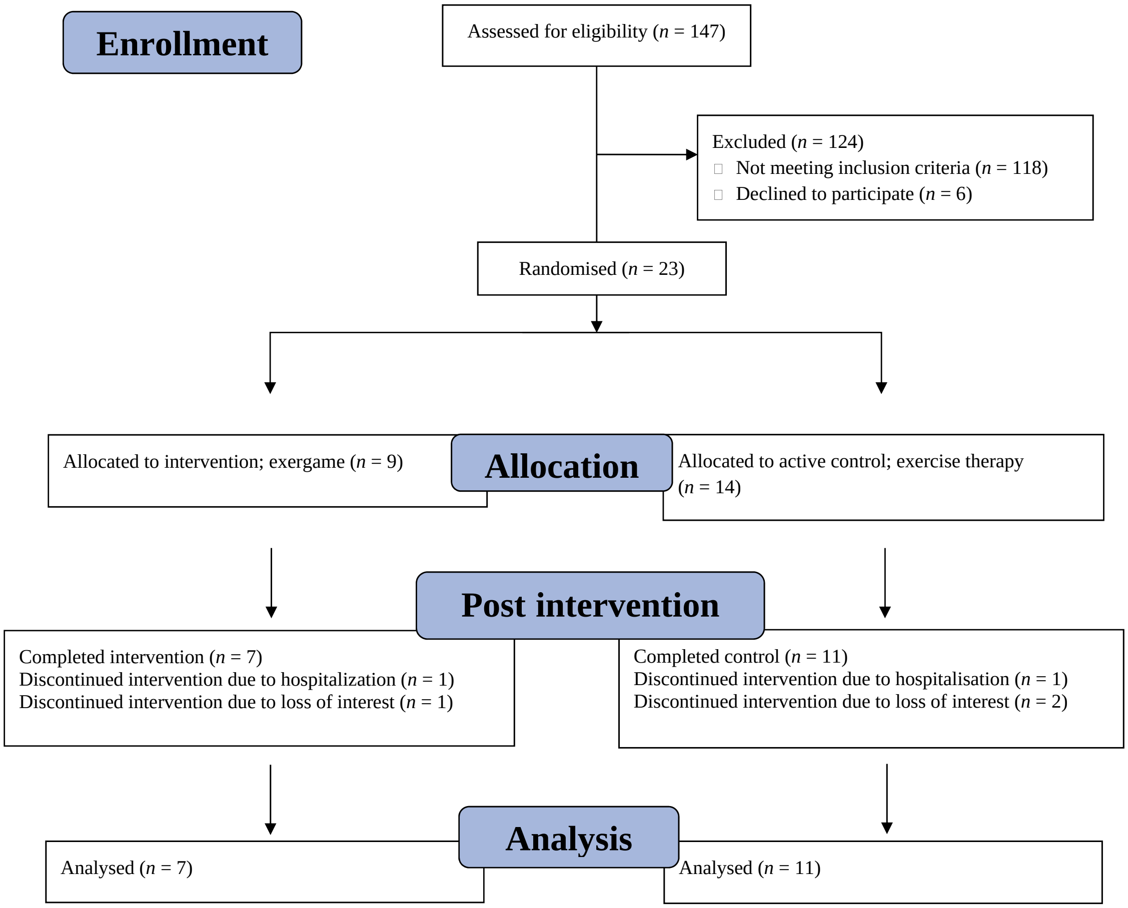

Figure 3. CONSORT diagram of participant flow.

minigames with a duration varying between 40 and 120 s. The participants played the minigames that were indicated by the exergame to achieve the same amount of training in each component. To ensure optimal load, the difficulty levels of the exergames were automatically adapted based on the scores achieved by the player. The strength training exercises also became more challenging after a certain number of plays. All participants were individually supervised by a facilitator to ensure safety and comfort. A Template for Intervention Description and Replication (TIDieR) checklist [59] was added in the online only Supplementary Table 1.

Active control intervention

Participants were invited to perform three individual exercise sessions per week for a period of 12 weeks, resulting in a total of maximum 36 sessions. Each session consisted of a 15-min walk and the performance of 15 min of standardised squatting and stepping exercises, which were like the exercises that were performed in the VITAAL minigames. These exercises were demonstrated and guided by a facilitator and did not include specific cognitive components. A conversation was held while walking. In this way, a dual task component was added to the physical training. These physical exercise sessions were added to care as usual.

Feasibility outcomes

The feasibility of the VITAAL exergame program was evaluated across five key areas of focus [29]. *Acceptability* of the participants regarding the exergame program was assessed by extracting relevant information from the semi-structured interviews and field notes. A semi-structured interview was carried out individually after six (mid-intervention) and after 12 weeks (post-intervention) of VITAAL exergame training. In this way, experiences were explored on two different moments in the program such that more thorough information could be assembled. Participants were interviewed face-to-face in the intervention room to stimulate recall of the exergame experiences. Open and close-ended questions were asked regarding the experiences, advantages, and disadvantages of participation in the VITAAL exergame program. The interviewer actively asked about positive and negative experiences and feedback. The interviews were recorded, and no written notes were taken during the interview to focus attention on the participant. Prompts were provided in the interview protocol to ensure that sufficient information was obtained on specific topics [60]. The recorded interviews lasted between three and 12 min (mean duration four minutes). The interview guide is included in the online only Supplementary Table 2. The facilitator of the sessions was also the interviewer. Every interview was transcribed, and transcripts were not returned to participants for extra comments or correction to limit additional burden.

Guidelines for best practice qualitative research in older adults with MNCD were applied [61,62]. The interviewer maintained a respectful attitude, made eye contact, used a calm voice, and avoided contradicting statements or asking about details. The interviewer was always aware of the communication challenges that the participants faced such as word-finding difficulties, abstract reasoning, memory deficits, fluctuating awareness, and limited attention and concentration. Effective communication strategies were applied, such as simplifying the structure of questions, allowing more response time, and redirecting the dialogue to the topic when necessary. *Demand* was assessed by recording the number of residents that participated in the exergame program versus the total number of residents in the long-term care facility. *Implementation* was assessed by keeping an exergame logbook that was completed by the facilitators. Notes regarding participants' behaviour and feedback were kept in a personal log file per session. During system use, the facilitator took handwritten field notes to record safety concerns, additional instructions, required physical support, and participant comments during exergaming. Attendance rates were calculated as well. Attendance sheets were completed each session to record the number of training sessions. Attendance rates were calculated by dividing the number of attended training sessions by the maximum possible number of training sessions (36 sessions). An attendance rate of 70% or higher (minimum 25 attended out of 36 planned sessions) was considered as being adherent to the exergame or exercise program [63]. Participants signed an informed consent stating that they were not obliged to give a reason for non-attendance or drop-out. Therefore, it was not possible to report reasons for non-attendance. *Practicality* was assessed by describing adverse events that occurred during or after exergaming. In addition, other events that prevented participation and that were being reported by the participant or facilitator were noted. *Preliminary efficacy testing* was examined by assessing differences in physical, cognitive, and mental health scores following an exergame program versus a traditional exercise program. The outcome measures that were assessed are described next.

Preliminary efficacy outcomes

Short physical Performance Battery (SPPB)

Balance, comfortable gait speed, and lower limb strength were assessed with the SPPB [37,38]. It comprises three subtests: a hierarchical standing balance test, a short four-meter walk at usual pace and five chair rises. The maximal total score is 12 and score ranges indicate mobility levels. Total scores between 10 and 12 indicate good functioning and no risk of mobility disability, total scores between four and nine indicate an elevated risk of mobility disability, and scores between zero and three indicate an already present mobility disability. Although concerns have been expressed regarding the feasibility and validity of quantitative functional assessments in older adults with MNCD [64,65], the reliability of the SPPB is high in older adults with and without MNCD, with intraclass correlation coefficient (ICC) values ranging from 0.82 to 0.92 [66–68]. SPPB test instructions were concise and repeated when needed, and tasks were presented by the facilitator [64]. Participants were allowed to use their assistive devices such as a walker or a walking cane during the four-meter walk test.

One-minute sit-to-stand test (1MSTST). The exercise capacity and leg muscle strength were assessed with the one-minute sit-to-stand 1MSTST. The number of times that the participant rose from a standard chair with the arms crossed in front of the upper body in one minute was counted [36,69,70]. The reliability in healthy and patient adult populations is high with ICC values ranging from 0.80 to 0.98 [36].

Mini-Mental State examination (MMSE)

The MMSE is a paper and pencil test that aims to assess cognitive functioning in individuals with MNCD. It was taken by a healthcare provider who was trained and experienced regarding this examination. It is an 11-question measure that includes several areas of cognitive functioning: orientation, registration, attention, calculation, recall, and language. The maximum score is 30 and a score of 23 or lower is indicative of cognitive impairment. The MMSE takes about ten minutes to administer and is therefore often used in clinical practice [39,40]. It has good internal consistency in individuals with MNCD (Cronbach's alpha = 0.62) [71].

Neuropsychiatric inventory (NPI)

Psychopathological issues were assessed with the NPI [41]. An interview was taken with a close caregiver. The included behavioural domains are delusions, apathy, hallucinations, disinhibition, agitation/aggression, irritability, depression/dysphoria, aberrant motor behaviour, anxiety, night-time behaviour disturbances, euphoria, and appetite and eating anomalies. Behaviour frequency is scored on a four-point scale, ranging from one to four. Symptom severity is scored on a three-point scale ranging from one to three. The NPI total score results from multiplying the frequency and severity rates per domain and adding them up. The NPI total score ranges from zero to 144. The test–retest reliability is 0.79 for behaviour frequency and 0.86 for symptom severity [72]. The Cronbach's alpha coefficient for the overall score is 0.88 [73].

Cornell Scale for Depression in dementia (CSDD)

Symptoms of depression were assessed with the observation-based CSDD. An interview was taken with a close caregiver who reported on observations of the residents' behaviour during the week prior to the interview. The CSDD consists of 19 items and each item is scored on a three-point scale ranging from zero to two [42]. A score zero indicates absence of the behaviour, a score one indicates mild or intermittent behaviour expression, and a score two indicates that behaviour is severely present. The items are classified in five categories: mood, behavioural disturbance, physical signs, cyclic functions, and ideational disturbance. The CSDD has adequate internal consistency and reliability in an older, frail nursing home population with MNCD. Cronbach's alpha is 0.81 and the kappa values of two studies included are 0.57 and 0.91 [74].

Dementia quality of Life (DQoL) questionnaire

Quality of life was assessed with the DQoL questionnaire [44], which was administered in the form of an interview with the participant. It consists of 29 items, measuring five domains in individuals with MNCD: self-esteem (four items), positive affect (six items), negative affect (11 items), feelings of belonging (three items), and sense of aesthetics (five items). A higher score per domain reflects better QoL, except for the negative affect dimension. Cronbach's alpha coefficient for internal consistency ranges from 0.71 to 0.84. The ICC for test-retest reliability ranges from 0.69 to 0.80 [43].

Data analysis

Feasibility analyses. Multiple readings of the interviews were completed during data analysis, combined with the written observations that were taken during exergaming. The audio files were transcribed in Microsoft Word format and entered in NVivo 12. NVivo 12 Microsoft software (© QSR International Pty Ltd., Victoria, Australia) was used for management and analysis of the qualitative data [75,76]. A thematic analysis was performed through six steps [77,78]. The first step involved repeatedly reading the interview transcripts. Next, initial codes were created by open coding, i.e., the process of indexing or categorising the text to assemble a framework of related thematic ideas. Subsequently, the remaining data were re-examined with axial coding, and codes were related to possible sub-codes. The codes were then compared for similarities and differences, and codes with similar contents were merged. The remaining categories were further interpreted and abstracted into four remaining themes. Although the interview transcripts formed the primary data set, the field notes complemented the overarching themes that were derived from the interview transcripts. Analysis of the field notes did not result in new categories or themes.

Preliminary efficacy analyses. Differences in demographic characteristics between the experimental and control groups were tested with the Mann-Whitney *U* test. Differences in categorical variables were tested using Fisher's exact test. Data were screened for normality using the Shapiro-Wilk test. Since the outcome data were not normally distributed, differences in post-outcome scores between the exergame and traditional exercise group were analysed with Quade's non-parametric Analysis of Covariance (ANCOVA). Although there were no significant differences in baseline values between the experimental and control group, we corrected for the baseline values, as stated a-priori in the protocol. The participants that dropped out were not included in the analysis. Partial eta-squared ($\eta^2 p$) effect sizes were calculated where for significant outcomes a $\eta^2 p$ of 0.01 to < 0.06 was considered small, 0.06 to < 0.14 medium, and 0.14 or higher considered as a large effect size [79]. Within-group pre-post differences were investigated with Wilcoxon Signed-Rank Tests. The statistical significance level was set at $p < 0.05$. Statistical analysis was performed using the statistical package SPSS version 28.0 (SPSS Inc., Chicago, IL). Recommendations for mixed methods research by Creswell (2015) [80] were used to integrate findings from qualitative and quantitative information of the study.

Results

Participants (demand, implementation, and practicality)

All the 147 residents living in long-term care facility de Wingerd in Leuven, Belgium during the study were screened for inclusion. Six participants refused participation and 118 did not meet the inclusion criteria. Main reasons for exclusion were limited comprehension of the study or mobility impairments due to a more advanced stage of MNCD. Twenty-three participants consented to participate in the study and were randomly assigned to the experimental group ($n = 9$) or the active control group ($n = 14$). Three participants dropped out because they lost interest during the intervention program, one of which from the intervention group and two from the active control group. One participant from the active control group had a fall incident after performing the control condition on her way back to her residence. Her participation had to be interrupted because of hospitalisation. One participant from the exergame intervention group had a fall incident during the weekend, which was independent from participation in the study. She had to be hospitalised due to hip fracture surgery and could not finish her participation in the trial. Finally, 18 participants completed the study of which seven were in the experimental group and 11 in the active control group. The participant flow chart is illustrated in Figure 3. Supplementary Table 3 gives an overview of the characteristics of the included participants. They had a mean age of 83.2 ± 6.5 (66–91) years, a SPPB score of 7.3 ± 2.4 (4–12), and a MMSE score of 17.2 ± 5.5 (9–23). Only one male participant was recruited and included in the active control group, resulting in 94.4% female participants. There were no significant differences in age and in sex distribution between both groups. A more detailed description of participant characteristics can be found in Table 2.

Thematic analysis results (acceptance)

Seven participants were interviewed after six and 12 weeks of participation, which resulted in 14 interviews. The analysis of these interviews, supplemented with the facilitators' field notes, revealed three main themes describing the experiences of the participants: (1) health effects; (2) motivators; and (3) barriers.

Health effects. Sleep. Five interviewees stated that the exergame program did not influence their sleeping pattern ($n = 5$, 71.4%). Other participants could not answer this question because they did not recall the effects or could not link the exergame intervention program to effects on their sleeping pattern.

> I don't think so. Nothing remarkable. (P5, post-intervention)

> No, what effect would it have on my sleeping pattern? It is now morning, and I will not go to sleep until tonight. (P7, mid-intervention)

Mental health effects. When asked if exergaming induced positive effects in mental health, three interviewees answered positively ($n = 3$, 42.9%). They did not explain the effects in more detail.

> I was glad that it worked out so well for me. (P3, post-intervention)

> I got a nice feeling. (P1, mid-intervention)

Attention and concentration. Six participants were not able to indicate whether the exergame program improved attention and concentration because they experienced difficulties understanding the question or did not recall the effects. Only one participant noticed some improvements in attention and concentration ($n = 1$, 14.3%).

Memory. Four participants indicated that they did not feel any effects on memory ($n = 4$, 57.1%).

Physical health. Two participants reported improvements in general physical health ($n = 2$, 28.6%). They however did not explain these improvements more thoroughly. Five participants stated that they did not feel any effects on physical health ($n = 5$, 71.4%).

> My physical health is actually pretty good [now]. (P7, post-intervention)

Cardiorespiratory fitness. One participant reported that her cardiorespiratory fitness levels did not deteriorate ($n = 1$, 14.3%). Three interviewees said that they did not experience any effects on cardiorespiratory fitness ($n = 3$, 42.9%).

> Let me put it this way … it did not deteriorate. (P2, mid-intervention)

Motivators

Participants generally felt comfortable playing the exergames. A variety of factors that motivated them were expressed and summed up below.

Enjoyment. The positive feelings that the interviewees described were all contemplated under the broad term of enjoyment. All participants reported that they enjoyed exergaming ($n = 7$, 100%).

> I can't say what I liked most about it because it was all good. (P1, mid-intervention)

> I can't name anything that was unpleasant. (P1, mid-intervention)

Table 2. Participant characteristics ($n = 18$).

Variables and sub-categories	Exergame intervention group ($n = 7$)	Active control group ($n = 11$)	p[a]
Age in years, mean ± standard deviation (range)	81.9 ± 8.2 (66-90)	84.2 ± 5.9 (71-91)	0.60
Sex, *n* (%)			
Male	0 (0)	1 (9.1)	> 0.999
Female	7 (100)	10 (90.9)	> 0.999
Montreal Cognitive Assessment, mean ± standard deviation (range)[b]	8.7 ± 7.3 (1-18)	11 ± 3.9 (5-16)	0.66
Mini-Mental State Examination, mean ± standard deviation (range)[c]	15 ± 6.7 (9-24)	18.6 ± 4.3 (12-25)	0.25
Short Physical Performance Battery, mean ± standard deviation (range)[d]	6.4 ± 1.9 (5-9)	8.2 ± 2.6 (4-12)	0.25
Diagnosis			
Alzheimer's Disease, *n* (%)	5 (71.4)	6 (54.5)	0.62
Vascular Dementia, *n* (%)	0 (0)	1 (9.1)	> 0.999
Neurocognitive Disorder not otherwise specified, *n* (%)	2 (28.6)	3 (27.3)	0.55
Frontotemporal Dementia, *n* (%)	0 (0)	1 (9.1)	> 0.999
Somatic comorbidities			
Diabetes, *n* (%)	3 (42.9)	1 (9.1)	0.27
Heart disease, *n* (%)	5 (71.4)	5 (45.5)	> 0.999
Hypertension, *n* (%)	5 (71.4)	7 (63.6)	0.73
Dizziness, *n* (%)	1 (14.3)	3 (27.3)	0.27
Urinary incontinence, *n* (%)	2 (28.6)	1 (9.1)	0.53
Use of walking aid, *n* (%)	2 (28.6)	1 (9.1)	0.53
Fear of falling			
Never, *n* (%)	3 (42.9)	8 (72.7)	0.20
Sometimes, *n* (%)	2 (28.6)	2 (18.2)	> 0.999
Regularly, *n* (%)	1 (14.3)	0 (0)	> 0.999
Always, *n* (%)	1 (14.3)	1 (9.1)	> 0.999
Physical activity level before participation			
No physical activities, *n* (%)	2 (28.6)	4 (36.4)	0.53
One walking session per week, *n* (%)	0 (0)	4 (36.4)	0.12
One to three walking sessions per week, *n* (%)	2 (28.6)	1 (9.1)	0.53
More than three walking sessions per week, *n* (%)	3 (42.9)	2 (18.2)	0.55

[a]*p*-values of group comparisons refer to Mann-Whitney U tests for continuous variables and Fisher's Exact tests for categorical variables.
[b]scores on the Montréal Cognitive Assessment range from 0 (severe impairment) to 30 (no impairment).
[c]scores on the Mini-Mental State Examination range from 0 (severe impairment) to 30 (no impairment).
[d]scores range from 0 to 12 and higher scores indicate higher levels of functional status.
Significant when $p < 0.05$.

> It's good. I wouldn't want to do it every day because that would be too much. (P2, mid-intervention)

> I always say to myself, I am here now, and I will do my best to catch them all. (P6, post-intervention)

Challenge. It appeared that participants liked that they were challenged, and they enjoyed learning something new ($n = 2$, 28.6%).

> Going someplace and getting the chance to do something different. (P2, mid-intervention)

> It's something different. (P2, mid-intervention)

> It was something new and the more you got into it, the better it went. I had days when it went really well, and days when it did not. (P5, post-intervention)

Exergame sounds. During the games, sounds were played to enhance the game experience or to provide helpful tips or feedback. Five participants stated that they really liked the sounds ($n = 5$, 71.4%).

> It's okay when it is not too loud. (P7, mid-intervention)

> It was all right. (P5, mid-intervention)

One participant did not report hearing any sounds during exergaming or was not able to recall this ($n = 1$, 14.3%).

> Did we hear music or sounds? I don't remember. (P1, post-intervention)

In contrast, one participant found the sounds unnecessary ($n = 1$, 14.3%).

> For me, it is unnecessary. (P7, post-intervention)

Sense of safety. When asked about the sense of safety, the participants unanimously reported feeling safe during the exergame sessions ($n = 7$, 100%). No fall incidents or injuries occurred during the exergame sessions.

> Yes, because there is always guidance. (P6, mid-intervention)

> Yes, otherwise I would not participate. (P6, post-intervention)

Intensity. The intensity of the sessions was perceived as good and not too strenuous by all participants ($n = 7$, 100%). The squatting exercises were perceived as the most challenging of all minigames ($n = 7$, 100%). The system automatically obligated the participants to take a break in the squatting minigame. They were always free to choose whether they wanted to maintain a standing position or take a seat while resting.

It was okay. (P6, post-intervention)

It wasn't too hard at all. (P7, mid-intervention)

Oh no, it was really easy for me … It did not bother me at all. (P1, mid-intervention)

Complexity of the games. Four participants stated that the exergames were not complex ($n = 4$, 57.1%). It was not too complicated, nor too effortless for them to understand the instructions and perform the required movements to play the games.

> No, not the movements … It's just the head. (P1, post-intervention)

> No, I can't say that it was too difficult. (P2, mid-intervention).

> Some games were difficult, but variety is important. (P5, post-intervention)

One participant admitted that she experienced the games as too complex for her ($n = 1$, 14.3%).

It's not easy. (P3, mid-intervention)

Interaction with the facilitator. Participants were always guided during displacements in the long-term care facility and during exergame performance. In all cases, they reported the overall interaction with the facilitator as positive ($n = 7$, 100%).

It was okay, we all have our tasks to fulfil. (P2, mid-intervention)

You do what you have to do. (P7, post-intervention)

It was good, very good. (P5, post-intervention)

Continuation of the program. After six and after 12 weeks of exergaming, participants were asked if they would be interested to continue participation in the exergame program. During the interview after six weeks of exergame training, all participants expressed a wish to continue participation in the exergame program ($n = 7$, 100%).

Absolutely, certainly at this age… You shouldn't sit too much. (P1, post-intervention)

It's good for my brain, so I will keep on attending. Duty calls. (P7, mid-intervention)

After twelve weeks, only one participant said that she would no longer be interested in participating in the exergame program ($n = 1$, 14.3%).

Well, enough is enough. (P5, post-intervention)

Barriers

A common experience amongst interviewees was that playing the exergames was comfortable and enjoyable. When the interviewer actively asked about negative experiences, responses were positive as well ($n = 6$, 85.7%).

I can't say anything negative about it. Sometimes I made a mistake, but that was my doing, and it was not because of the game. It was me. (P1, mid-intervention)

No, I couldn't say anything negative about it (P5, mid-intervention)

Some barriers were also determined and summed up below.

Disliking games. Only one participant revealed that she did not like playing games and therefore not always attended the exergame sessions ($n = 1$, 14.3%).

I don't really like playing games. (P7, post-intervention)

Negative effects. One participant reported that she felt unwanted effects in her eyes and knees that were caused by exergaming ($n = 1$, 14.3%).

It's located in my eyes, but I don't know if others feel it too. (P5, mid-intervention)

My knees hurt when I performed squats. (P5, post-intervention)

Attendance and safety

The mean attendance rate was 61% in the exergame intervention group and 63% in the active control group. One participant in the exergame intervention group and one in the active control group reached an attendance rate of more than 70% of the sessions, which was deemed to be adherent to the exergame intervention or active control program [63]. The self-reported experienced training intensity while exergaming was mild. However, the squatting movements were experienced as strenuous. One participant reported feeling faint and one reported knee pain while squatting. One participant from the active control group had a fall incident after performing the control condition during her walk back to her residence. She tripped over an obstacle and her facilitator was not able to prevent her from falling in due time. There were no other study-related adverse events reported by the participants, nor observed by the involved researchers.

Preliminary efficacy results

Between-group differences

The means and standard deviations of the pretest and posttest battery scores for the exergame intervention and active control group and the P values, F values, and partial eta squared (η^2_p) for the between-group post-score differences are depicted in Table 3. The MMSE post-score score was better in the exergame intervention group ($\eta^2_p = 0.02$, $p = 0.01$, i.e., small effect) compared with the active control group. Table 4 however did not demonstrate differences in between-group MMSE subdomain post-scores. There were no significant differences in SPPB ($\eta^2_p = 0.00$, $p = 0.27$), 1MSTST ($\eta^2_p = 0.03$, $p = 0.39$), NPI ($\eta^2_p = 0.01$, $p = 0.09$), CSDD ($\eta^2_p = 0.02$, $p = 0.44$), and DQoL ($\eta^2_p = 0.18$, $p = 0.12$) post-intervention scores between the exergame intervention and active control group.

Within-group differences

Within-group analyses did not demonstrate differences between MMSE ($z = -1.21$, $p = 0.22$), SPPB ($z = -0.27$, $p = 0.79$), 1MSTST ($z = -0.11$, $p = 0.92$), NPI ($z = -0.68$, $p = 0.50$), CSDD ($z = -0.95$, $p = 0.34$), and DQoL ($z = -1.73$, $p = 0.08$) pre-post scores in the exergame intervention group. Similarly, in the active control group no differences between 1MSTST ($z = -0.98, p = 0.31$), NPI($z = -1.64$, $p = 0.10$), CSDD($z = -0.35$, $p = 0.72$), and DQoL ($z = -1.37$, $p = 0.17$) pre-post scores were found. However, in the active control condition group the MMSE ($z = -2.51$,

Table 3. The physical, mental and cognitive effects of exergaming versus an active exercise control condition in residential older adults with a major neurocognitive disorder.

	Intervention ($n = 7$)		Control ($n = 11$)				
Variable	Pre-test (mean ± SD)	Post-test (mean ± SD)	Pre-test (mean ± SD)	Post-test (mean ± SD)	P	F	η^2_p
SPPB	6.4 ± 1.9	6.7 ± 2.2	7.9 ± 2.6	6.5 ± 3.0	0.270	1.3	0.00
1MSTST	15.1 ± 4.9	15.3 ± 6.2	14.2 ± 9.3	11.9 ± 8.7	0.389	0.8	0.03
MMSE	15.0 ± 6.7	17.1 ± 7.2	18.6 ± 4.3	15.7 ± 4.9	0.012*	8.1	0.02
NPI	10.1 ± 11.4	10.4 ± 11.9	16.4 ± 19.2	4.3 ± 4.3	0.086	3.4	0.01
CSDD	6.7 ± 3.0	5.9 ± 2.3	7 ± 4.9	6.9 ± 4.7	0.438	0.6	0.02
DQoL	3.0 ± 1.2	3.4 ± 1.0	2.9 ± 0.5	2.8 ± 0.4	0.116	2.8	0.18

Significant when $p < 0.05$ using Quade's non-parametric analyses of covariance with post test scores as dependent variables, groups as independent variables, and baseline scores as covariates. 1MSTST: one minute sit to stand test (performance of as many sit-to-stand actions as possible in 1 min without using the upper limbs); CSDD: Cornell scale for depression in dementia (range = 0 to 38, and a score below 6 is associated with absence of depressive symptoms, and scores above 10 indicate probable major depression); DQoL: Dementia quality of life (scores range from 1 (poor QoL) to 5 (excellent QoL)); MMSE: mini-mental state examination (total scores range from 0 to 30 with lower scores indicating more cognitive impairment); NPI: neuropsychiatric inventory (12 item score with a range of 0 to 12 per item); SPPB: short physical performance battery (total scores range from 0 to 12 with lower scores indicating a higher risk and a score lower than 10 indicates one or more mobility limitations).

Table 4. The effects of exergaming versus an active exercise control condition on MMSE subscores in residential older adults with a major neurocognitive disorder.

	Intervention ($n = 7$)		Control ($n = 11$)				
Variable	Pre-test (mean ± SD)	Post-test (mean ± SD)	Pre-test (mean ± SD)	Post-test (mean ± SD)	p	F	η^2_p
MMSE Orientation in time	1.7 ± 2.0	1.5 ± 2.0	1.4 ± 1.3	1.4 ± 1.5	0.89	0.02	0.002
MMSE orientation in space	1.9 ± 1.6	2.2 ± 1.5	3.0 ± 1.2	2.1 ± 1.6	0.12	2.68	0.001
MMSE recall	2.7 ± 0.8	2.7 ± 0.8	3.0 ± 0.8	2.2 ± 1.3	0.16	2.22	0.046
MMSE attention	1.3 ± 2.2	2.8 ± 2.3	3.1 ± 2.5	2.7 ± 2.4	0.35	0.91	0.001
MMSE memory	0.7 ± 1.2	1.1 ± 1.2	0.2 ± 0.4	0.1 ± 0.3	0.39	0.79	0.034
MMSE language	6.4 ± 1.0	6.2 ± 1.8	7.4 ± 0.7	6.6 ± 1.6	0.09	3.35	0.02
MMSE praxis	0.3 ± 0.5	0.6 ± 0.5	0.7 ± 0.5	0.6 ± 0.5	0.23	0.63	0.001

Significant when $p < 0.05$. MMSE: mini-mental state examination (total scores range from 0 to 30 with lower scores indicating more cognitive impairment).

$p = 0.01$) and SPPB ($z = -2.54$, $p = 0.01$) reduced significantly post versus pre.

Discussion of integrated findings

This mixed methods study investigated the feasibility of the VITAAL exergame prototype in individuals with MNCD residing in a long-term care facility. With regards to the feasibility of the VITAAL exergame prototype, the interpretations of the mid-intervention and post-intervention interviews revealed three themes regarding the participants' experiences, i.e., health effects, motivators, and barriers. In this discussion, these themes will be elaborated and interpreted together with the facilitators' observations and the preliminary efficacy outcomes of the assessment scores.

Health outcomes

Some participants reported during the interviews that exergaming induced beneficial effects on their mental health. Our quantitative analyses furthermore demonstrated that following the exergame intervention post-scores for psychopathological issues, as assessed with the NPI [41], and symptoms of depression, as assessed with the CSDD [42], were similar with post-scores following traditional exercise. Since traditional exercise is known to be efficacious in individuals with MNCD in reducing psychopathology, as measured with the NPI [81], and in reducing depression [82], as measured with the CSDD, the current outcome data of the exergame intervention are encouraging.

Interviewers asked about cognitive effects such as attention and concentration as well. The improvements in attention and concentration were however not widely reported. In addition, most of the participants indicated that they did not feel any effects on memory. These findings are somehow in line with our quantitative analyses. Although the quantitative analyses showed significant higher post-MMSE scores following exergaming versus traditional exercise, one should notice the mean effects were small. A possible reason is that rather than improving MMSE scores, exergaming may play a role in preventing deterioration. Within-group analyses did demonstrate that while in the active control condition MMSE scores reduced significantly, no changes were observed in the exergame condition. The MoCA was not repeated since the burden on the participants was considered too high [83–86]. The current scientific evidence on the effects of exergaming on cognitive functioning in people with MNCD is mixed. While previous objective data from a randomised controlled trial reported that exergame training does not improve episodic memory, as assessed with the Location Learning Test-Revised in community-dwelling people with MNCD [87], another recent pilot randomised controlled trial investigating the effects of an eight-week stepping exergame program in residential individuals with MNCD did demonstrate beneficial cognitive effects [88]. Considering the present findings, it can be hypothesised that exergaming has the potential to maintain cognitive functioning over a certain period in people with MNCD, although more research is needed as the observed effects were small. The neuroprotective effects of exercise have been well documented. Exercise-induced increases in brain-derived neurotrophic factor, insulin-like growth factor-I, vascular endothelial growth factor, and homocysteine [89,90] promote structural and connectivity changes in the brain areas important for memory and executive function such as the frontotemporal lobes and hippocampus [91,92]. The lack of reported subjective improvements might also be due to the fact that participants could have failed to recall the effects. Another possible explanation is that, because the participants needed continuous verbal support due to the complexity of the games, the synergistic effects of exergaming may have been delayed [93]. The low attendance rates might explain the lack of reported and assessed health effects as well.

Improvements in general physical health were only discussed by a minority of the participants. They were not able to explain these improvements more thoroughly and, according to the guidelines for best practice qualitative research in older adults with MNCD [61,62], they were not extensively asked for detailed explanations. Most participants stated that they did not feel any effects on general physical health nor on cardiorespiratory fitness levels. The SPPB and DQoL scores of the exergame intervention group showed similar post-scores after 12 weeks of exergaming. Based on these data, we did not find a significant difference in physical functioning. On the other hand, similar with the MMSE scores, within-group differences did demonstrate that SPPB scores reduced in the active control condition and not in the exergame condition. Larger trials are however needed in order to confirm whether exergaming may maintain or improve balance, gait, and physical performance in long-term care facility residents with MNCD.

Motivators

Participants were individually guided and reported feeling comfortable while playing the exergames. They all stated that they enjoyed exergaming, and this was confirmed in the facilitators' observations that reported expressions of pleasurable feelings. Moreover, participants said that they appreciated being challenged, and that they liked being taught something new. This is in line with findings of a recent qualitative study investigating the experiences of participation in a stepping exergame program.

Although a different exergame device was used and the duration of the exergame program was only eight weeks, it was suggested that individuals with MNCD enjoyed exergaming and liked the challenge of learning something new as well [24]. While exergaming, sounds enhanced the game experience or provided helpful tips or feedback and most of the participants stated that they liked the sounds while exergaming. Of importance for people with MNCD is that all participants unanimously reported feeling safe during the exergame sessions. One of the reasons might be that when executing the VITAAL exergame, participants are allowed to use extra physical support from their walker or a chair. The field notes revealed no fall incidents nor injuries during exergame performance. The physical intensity levels of the sessions were perceived as agreeable, and participants said on both interview moments that the exergames were not too strenuous. The squatting game was perceived as the most challenging game because it was physically more intense. Performing squats obviously places a higher load on the muscles (e.g., quadriceps muscles) than performing multidirectional steps. Sarcopenia, which is the loss of skeletal muscle mass and function with advancing age [94], might have contributed to the strenuous feelings when performing squats. The 1MSTST scores of the exergame intervention group showed no differences after 12 weeks and this was the case in both the exergame intervention and the active control group. A reason could be that, although the facilitator corrected to ensure correct posture, the knee bend of the squats was not performed deep enough. As a result, the quadriceps, glutes, hamstrings, and hip flexors, which are the primary muscles involved in this exercise, were not sufficiently challenged.

Many of the participants stated that the exergames were not too difficult for them to understand. However, the field notes revealed that all participants experienced difficulties in understanding the instructions and needed to be extensively guided while playing. For example, instructions were often repeated when the player was not able to remember how to play or navigate to the next game. The next version of the prototype could be adapted to provide a simpler exergame experience in residential individuals with MNCD. The overall interaction with the facilitator was also unanimously experienced as positive. It might be hypothesized that the individual guidance and extra verbal motivation of the facilitators induced a more positive feeling towards the exergame program. From this finding, the importance of prompts given by the facilitator when learning individuals with MNCD to use technological devices becomes evident. Previous research already indicated that verbal prompts (i.e., instructional words), gesture prompts (i.e., steps modelled using physical movements), and physical assistance (i.e., any physical intervention) are essential for individuals with MNCD when learning to use motion-based technologies such as exergames [95]. Moreover, the importance of supervision of a trained facilitator in exergame interventions in individuals with MNCD has been highlighted in systematic reviews [20, 96]. It can be concluded that individuals with MNCD need continuous guidance by a trained facilitator while exergaming.

After six weeks of exergaming, all participants expressed a wish to continue participation in the exergame program. After twelve weeks, only one participant reported that she was no longer interested in continuing participation in the exergame program.

Barriers

In general, participants enjoyed exergaming. When the interviewer actively asked about negative experiences, participants responded positive as well. One barrier that was mentioned was feeling unwanted effects while performing squats, such as pain located in the knees or feeling faint. Another barrier was derived from the facilitators' field notes. More specifically, it was written down that the games were complex for the participants. This finding corresponds to the findings of the usability study of the VITAAL exergame prototype [28]. In this usability study, facilitators reported that residential older adults with MNCD experienced difficulties in understanding the exergame instructions, and this during one try-out session. In addition, the exergames were considered mentally exhausting [28]. Here, the overall system usability scale score was 57.8, which corresponds to a system usability that is ok to good [97]. In this study, participants needed additional verbal guidance and nearly half of them was not able to play without constant verbal guidance of the facilitator. It was hypothesised that these difficulties could be attributed to the fact that they only had one try-out session, which was not sufficient to get familiarised with the instructions and execution of the exergames. Our findings, however, question this hypothesis. It may well be that the extensive support and motivation from the facilitator during exergaming helped the participants feel more confident while playing. From previous research, it is known that the persons' attitude toward technology is crucial for system adoption as well. Having a positive attitude towards technology and having previous positive experiences are known to improve adoption [98,99]. Negative attitudes such as lack of technology acceptance and technology burden can act as barriers, resulting in not adopting the system [100]. Lack of confidence with technology and, more specifically exergaming, was not examined. However, all participants showed a positive attitude towards exergaming.

Limitations

Some limitations of this study need to be considered. For example, the generalisability of the research is limited. Only residents from one long-term care facility were recruited, so the current findings may have limited applicability to other settings such as day care, hospital care, or rehabilitation. Moreover, only volunteers were included in the trial. Being willing to participate in an exergame program might reflect an exceptional motivation for physical activity or a higher interest in technological devices. Therefore, the current findings cannot be generalised to all residential individuals with major neurocognitive disorder. Also, more female participants (94.4%) were included. This over-representation could be because women are at greater risk for developing Alzheimer's Disease [101], and consequently more women are living in long-term care facilities, also in Belgium [102]. Only a minority of the residents were eligible for inclusion in this study. More specifically, 18 of the 147 residents residing in the long-term care facility who were screened, were included. The main reason for non-inclusion was being in an advanced stage of MNCD which prevented participation due to cognitive or physical limitations. Researchers previously suggested that only one in five residents with MNCD can participate in an exergame training program [103]. Also, residents with more severe cognitive impairments are more likely to reject participation in exergame programs [104]. Another limitation is that data regarding experiences of participation in the exergame program may have been influenced by social desirability bias [105]. The interviewer attempted to address this by actively asking about negative experiences of exergaming as well. In addition, a neutral facial expression and body language were adopted as to limit influencing the participants' responses. Despite these provisional measures, social desirability bias cannot be completely ruled out [106]. Moreover, to increase familiarity and comfort, the interviewer and facilitator of the exergame session were the same person. The fact that the same person acted as facilitator and interviewer may have amplified this bias, as the participants may want to please the person who accompanied their training. Another important note is that we did not control for the effect of adjuvant pharmacological treatments including for example cholinesterase inhibitors, memantine, typical and atypical antipsychotics, antidepressants, and benzodiazepines, although it is known they can act as potential confounders and disruptors in MNCD research [107]. The experiences regarding participating in the active control intervention were not examined through interviews. It would have been interesting to compare the experiences of participating in an exergame program with those in the traditional exercise program. It could be that exergames offer a more enjoyable experience than traditional exercise programs. Six participants in the exergame intervention group and ten participants in the active control group did not reach a minimum of 70% adherence to the training program. The small sample size and low attendance rates might explain the lack of significant differences in outcomes between the exergame and traditional exercise conditions. Last, the baseline MMSE score in the exergame intervention group was 15, which was lower than the baseline score in the active control group. This lower score in the exergame intervention group could have enabled less decline compared to the active control group.

Future research

Opportunities for future research could include further refinement of the VITAAL exergame prototype to simplify the minigames and include continuous automatic adaptation to the individuals' level of functioning while playing the minigames. In addition, the usability and feasibility of this adaptation of the VITAAL exergame should be examined in individuals with MNCD residing in long-term care facilities. In this way, the preliminary results of this study can be confirmed or refuted. Also, including a passive control group in such studies would be interesting. Long-term follow-up of the effects of exergame training on the examined outcomes could explore possible maintenance effects. Large scale studies should also explore whether possible beneficial effects might differ between different diagnoses of MNCD and between different levels of MNCD severity.

Moreover, the dropouts in our trial due to fall incidents in the long-term care facility underscore the need for examining the efficacy of exergaming on gait and balance outcomes in individuals with MNCD residing in long-term care facilities. Furthermore, incidence of falls, fall related injuries, and fall efficacy should be explored since it has been demonstrated that step training can reduce falls by 50% in older adults in both community and institutional settings [108]. Future studies could examine the efficacy of a simpler version of the VITAAL exergame prototype and explore whether it could enhance training motivation in individuals with MNCD.

Conclusions

The findings of this mixed methods study suggest that the VITAAL exergame device was well accepted by individuals with MNCD residing in a long-term care facility. Extensive verbal guidance was however necessary to understand game instructions and play the exergames. The preliminary efficacy results revealed higher post-MMSE scores after 12 weeks of exergaming when compared with a traditional exercise program. While MMSE scores significantly reduced in the active control condition, MMSE scores were maintained following exergaming. However, data should be considered with caution due to some methodological shortcomings including a limited sample size. It is advised to further simplify the exergame prototype before the acceptance and efficacy can be explored in individuals with MNCD in a feasibility study.

Acknowledgements

The authors thank Jan Vanwezer, the residents, and staff at long-term care facility de Wingerd, and the master students from the KU Leuven Department of Rehabilitation Sciences for their participation and hospitality in the data collection process. The authors thank the developers of the VITAAL solution for providing the device and additional support.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was performed in the context of the project VITAAL AAL-2017-066, funded under the AAL Joint Program and co-funded by the European Commission and the National Funding Authorities of Portugal, Switzerland, and Belgium.

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Data availability statement

The original contributions presented in the study are included in the article. Further requests can be directed to the corresponding author.

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