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ARTICLE

Neuroboost: An Exergame Platform for Cognitive Training in Ageing

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ABSTRACT: Backgrounds: The term "exergame" refers to a specialised genre of video games that combine cognitive training with physical exercise. Increasing interest has emerged in utilising exergames as therapeutic tools for the rehabilitation of individuals with acquired cognitive deficits and for cognitive stimulation among institutionalised elderly individuals with limited independence. However, the proliferation of such technologies is rarely accompanied by rigorous studies assessing their validity, efficacy, and usability. This study aimed to introduce Neuroboost, an innovative platform designed to enhance cognitive functions through exergames targeting individuals with various acquired cognitive deficits, and to explore the feasibility of the platform. **Methods:** A pilot study was carried out to assess the impact of the platform on cognitive performance, mood, and quality of life in elderly participants (n = 4) who required substantial care. The patients underwent a pre-training and post-training neuropsychological assessment. Cognitive training was conducted using Neuroboost. Data regarding both the platform's usability and user satisfaction were also collected. **Results:** The training program was associated with preliminary improvements in participants' performance on specific platform tasks and in selective cognitive domains as measured by standardised neuropsychological assessments. Importantly, the scores on the Beck Depression Inventory (BDI), Apathy Evaluation Scale (AES), and Quality_VIA reflected improvements in terms of mood and quality of life. Usability data revealed that while participants required frequent assistance during the initial sessions, the need for assistance diminished as they became more familiar with the system. Furthermore, analysis of participant feedback suggested that almost all the exercises tended to elicit positive reactions. **Conclusions:** These preliminary findings suggest that Neuroboost is an engaging and feasible tool for training cognitive functions and potentially improving the quality of life in elderly individuals with cognitive and motor impairments. However, future studies are needed to further validate these results and optimise the platform for broader clinical applications.

KEYWORDS: Exergames; cognitive rehabilitation; elderly population

1 Introduction

Video games have emerged as one of the most prevalent forms of entertainment. In recent years, however, there has been growing interest in applying gaming elements—such as dynamics, mechanics, and design techniques—to contexts beyond entertainment, including education [1–3], rehabilitation [4–8], and marketing [9–11]. This approach, known as "gamification" [12–15], involves the integration of game-based elements—such as leaderboards, badges, challenges, quests, and feedback mechanisms [16,17]—to create engaging and motivating user experiences [18].

A particular subset of gamification is serious games, which combine enjoyment with instructional objectives to achieve outcomes beyond pure entertainment [19–21]. While serious games have traditionally been applied in educational contexts to balance learning and play in line with the "learning by doing" approach [22,23], their use has expanded to clinical settings [24–31]. In clinical contexts, serious games have shown promise in the assessment and treatment of cognitive deficits associated with neurodevelopmental disorders (e.g., autism spectrum disorder [32], ADHD [33,34] and specific learning disorders) as well as neuropsychological syndromes resulting from brain injury (e.g., stroke, dementia [26,35–37]). Despite their potential, maintaining treatment adherence remains a challenge. For instance, patients with acquired cognitive disorders often demonstrate low participation in rehabilitation programs, with adherence rates dropping significantly for home-based interventions [38–40]. These issues are often attributed to the monotony and lack of engagement inherent in conventional therapeutic activities. Gamification, specifically through serious games, can address these limitations by turning the rehabilitation into a more engaging and dynamic activity [41–44].

Empirical evidence supports the efficacy of serious games in enhancing adherence and achieving cognitive improvements. For example, Van Der Kolk and colleagues [45] demonstrated that integrating gamified elements in a home-based intervention for Parkinson's disease patients significantly improved adherence, with a dropout rate of 5% and 95% adherence to prescribed exercises.

On the other hand, the application of serious games in computerised cognitive intervention (CCI) contexts is associated with significant gains in patients with brain injury [46–49]. Jung et al. [50] investigated the benefits of a serious game developed for cognitive training in patients with chronic stroke and mild to moderate cognitive impairment. In their study, the authors involved 50 patients: 25 were assigned to a control group receiving standard medical care, while the remaining 25 (i.e., the experimental group) underwent standard medical care and cognitive training through serious games. The results of the study showed that the experimental group exhibited improvement in overall cognitive functioning, short-term memory, and working memory. These improvements were not observed in the control group. The application of serious games in cognitive rehabilitation contexts has been associated not only with direct benefits, namely improvements in trained cognitive functions (near-transfer), but also with indirect benefits, namely improvements in untrained cognitive functions functionally related to those examined (far-transfer [51,52]). Evidence in that regard has been reported by Nitsan et al. [52]. In their study, the authors investigated the indirect benefits on language processing of executive function training through serious games for elderly subjects. The authors conducted a study on healthy elderly individuals assigned to an experimental group (undergoing cognitive training through serious games) and a control group (elderly individuals asked to carry out their normal daily routines). Interestingly, the results highlighted that the experimental group reported greater improvement in language processing tasks compared to the control group. The authors posited that the improvement of language processing might be an indirect benefit related to executive function enhancement.

Further evidence regarding the benefits associated with the cognitive training conducted through serious games has also been reported in patients with mild cognitive impairment (MCI [53–56]), Alzheimer's disease (AD [54,57,58]), or generally with dementia [59,60]. In a recent literature review and meta-analysis about the effectiveness of computerised cognitive interventions, Zuschnegg and colleagues [54] reported that 12 out of 18 randomised controlled trials conducted on patients with MCI showed significant effectiveness in the domains of memory and executive functions, but not in the overall cognitive functioning and language. Additionally, only 1 out of 6 studies detected the effectiveness of the computerised intervention for memory, while four other studies identified only a trend toward significance.

Despite the benefits brought by the gamification and the serious games to the clinical contexts, the use of this technology also possesses certain limitations. Among others, the most significant limitation is that, in an increasingly digital world, technological devices may lead to increased social isolation [61] and impact individuals' physical health (e.g., conditions associated with excessive sedentary behaviour, such as cardiovascular and metabolic diseases). For example, the sedentary nature of screen time poses a significant health risk, which has led to the development of active screen time and mobile device-linked games to address this issue [62–64].

In this regard, it has been described that learning and cognitive training may occur along with the physical activity [53,65,66] by means of a so-called "exergame". The exergame (a compound word of exercise and game [67,68]) refers to a genre of video games that combine cognitive training with physical exercise [69–71]. These games are based on technologies that also require body movement or some physical reaction to the stimuli presented to individuals through a monitor or projector. Exergames represent a shift away from the traditional perception of video games as a sedentary leisure activity, aiming instead to encourage physical activity and cognitive engagement across different demographics, including both healthy individuals and those with cognitive impairments (whether congenital or subsequent to an acquired brain injury).

As for the serious games, also the exergames are extremely versatile and applicable in different contexts, including clinical and educational settings. There is a growing body of literature reporting the effectiveness of cognitive rehabilitation and training, as well as a higher level of patient adherence and engagement in the proposed activities. For example, in clinical contexts, exergames have been used for motor rehabilitation [72–75], to make cognitive training more stimulating and dynamic [76–78], or in other cases, to rehabilitate both motor and cognitive deficits [38,78,79]. In an interesting review by Zhao et al. [60] the authors reported that 7 out of 10 studies highlighted that cognitive training provided via exergames was associated with a significant improvement of the treated cognitive functions. Accordingly, it can be assumed that exergames are a promising tool for cognitive and motor rehabilitation, or both, in a more dynamic and engaging context. Their versatility makes them applicable in various settings, such as the neurorehabilitation (motor-cognitive) of stroke patients, people with dementia, or more generally, in institutionalised elderly individuals [80–82].

At present, there are still few software programs in the literature proposing cognitive enhancement interventions combined with physical exercise. Additionally, the software available on the market does not always have a solid scientific or theoretical framework, nor is its application supported by adequate feasibility and usability data.

The present study aims to address these gaps by presenting the Neuroboost platform, designed for cognitive enhancement through body-mediated exercises, with a specific focus on hand movements. The focus on hand movements, rather than the full body, was prioritised in order to address specific safety and clinical requirements of the target population, namely elderly individuals, especially residing in nursing homes. In fact, in these settings, many elderly individuals face severe mobility limitations or are non-ambulatory, relying on wheelchairs for daily activities. Additionally, full-body interventions may pose a significant risk of falls, which can lead to adverse health outcomes in this population. By prioritising hand-based exercises, the intervention should ensure cognitive training for those patients with gait instability and functional impairments, allowing for both cognitive and motor engagement while mitigating the risk of physical injury.

Furthermore, the present work aims to provide preliminary data on the platform's feasibility and usability, with the ultimate purpose of advancing cognitive rehabilitation for individuals with acquired cognitive and motor impairments.

2 Neuroboost

2.1 General Description

Neuroboost is an integrated software-hardware system designed to advance cognitive rehabilitation in clinical settings through exergames, which combine cognitive training with physical exercise. The platform's structure is designed for versatility, facilitating: (1) neurorehabilitation activities for patients with acquired brain injury; and (2) cognitive-motor enhancement activities for institutionalised elderly individuals.

The development of Neuroboost was driven by three primary factors: (1) the increasing interest in applying gamified elements to rehabilitation settings; (2) the evidence supporting the efficacy of treatments employing this technology; and (3) the enhanced engagement and adherence observed when rehabilitation programs are delivered through exergames.

Guided by a thorough literature review, Neuroboost's design incorporates validated methodologies associated with positive clinical outcomes [83–86]. The platform operationalises cognitive processes commonly targeted in neurorehabilitation—such as attention, memory, executive functions (including cognitive flexibility, inhibition, and working memory), and language—while addressing deficits frequently observed in patients with acquired central nervous system lesions. These processes have been translated into dynamic and engaging exergames, enabling more effective cognitive assessment and rehabilitation for individuals with conditions such as stroke or dementia, as well as for those residing in institutional care.

A central focus of Neuroboost's design and development has been the creation of a rehabilitative environment that prioritises both clinical efficacy and active patient participation. By leveraging gamified principles and evidence-based interventions, Neuroboost aims to enhance the effectiveness, engagement, and adherence associated with neurorehabilitation practices.

2.2 The Architecture

The platform was designed and implemented using the Unity 3D game engine. Neuroboost was developed for use with a monitor or projector, a microcomputer (e.g., a mini PC), a webcam, and a mouse. However, the platform can be installed on any device running the Windows operating system and can utilise any webcam with technical specifications equal to or higher than those listed in Table 1.

The exercises are designed to be administered through a 24-inch monitor or larger. The software uses a Python library (MediaPipe Hands [87]) for the real-time detection of the users' hands from the video source captured by the webcam. MediaPipe is an open-source library developed by Google that provides a real-time hand detection and tracking system using computer vision techniques. Specifically, the MediaPipe Hand Landmarker identifies and locates key anatomical landmarks of human hands in a video stream in real-time. The system uses a Convolutional Neural Network (CNN) to detect hands in the initial video, which can be acquired from a webcam or another video source. Once the hand is detected, the system extracts relevant features and sends them to a second neural network that determines the approximate position of key landmarks such as the fingertips, finger joints, and palm base. The system detects the location of 21 knuckle coordinates within the detected hand regions (Fig. 1).

Table 1: The minimum system requirements are listed.

	OS	**Windows 10 Pro or Higher**
PC	Processor	Intel Core i3-12100 (4 core, 12 MB, 8 thread, da 3.3 GHz a 4.3 GHz, 60 W)
	RAM	8 GB DDR4 or higher
	Storage	SSD 256 GB or higher
Webcam	Video Details	Video output 1080p, 30 fps HDR Automatic exposition Automatic flicker reduction Wide 78° field of view Automatic white balance
	Input Devices	USB-A connection
	Sensors	1920 × 1080, 30 fps Pixel size: 1.4 μm × 1.4 μm

Note: OS: operating system; PC: personal computer; RAM: random access memory; MB: megabyte; GHz: gigahertz; DDR4: double data rate fourth generation synchronous dynamic random-access memory; SSD: solid state drive; HDR: high dynamic range.

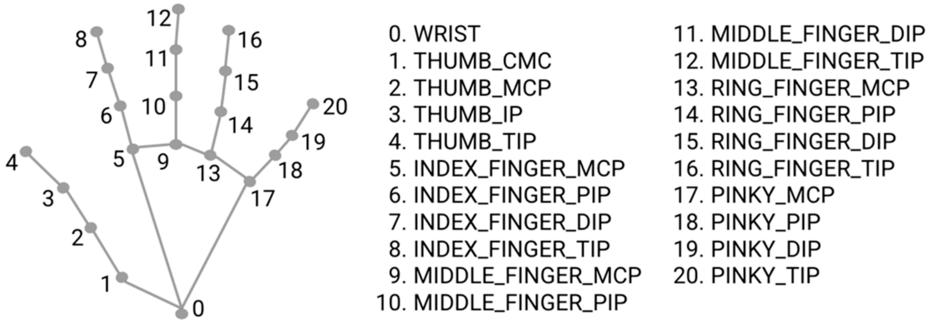


Figure 1: The 21 hand coordinates detected by the library are shown (image source: https://developers.google.com/mediapipe/solutions/vision/hand_landmarker).

The model was trained on approximately 30,000 real-world images containing hand images in different poses and angles, as well as various synthetic hand models rendered on different backgrounds. The trained model is considered highly reliable; for instance, Zhang et al. [87] reported an average precision of 95.7% in their ablation study. Additionally, an independent study of Amprimo et al. [88] explored the accuracy and reliability of the Google MediaPipe Hand (GMPH) and its depth-enhanced GMH-D framework against a gold-standard motion capture system (i.e., the Optitrack solution, including six Prime13 cameras with a resolution of 1280 × 1024 pixels). The results demonstrate high temporal and spectral consistency for both frameworks (GMPH and GMH-D) compared to the gold standard.

Once the hand landmarks are identified, the MediaPipe Hand Landmarker provides precise information about the position and orientation of hands in the image or video. The bundle contains two models: one for palm detection and one for hand landmark detection. The palm detection model identifies hands within the input image, while the hand landmark detection model identifies specific hand landmarks on the hand image defined by the palm detection model.

To enable communication between Unity and Python 3, a UDP socket is used. This is a form of network communication that utilises datagrams (i.e., independent data packets). To establish a UDP connection, the following steps are required (a schematic representation of the steps is provided in Fig. 2):

(1) Socket creation: Both the sender and the receiver must create a UDP socket. A socket is a software abstraction that represents a communication endpoint through which data can be sent and received.
(2) Binding the socket to the IP address and port: The sender and receiver must bind their sockets to a specific IP address and port. The IP address identifies the device (or host) on the network, while the port specifies a specific application running on that host.
(3) Sending datagrams: The sender can send one or more datagrams containing the desired data. Each datagram has a maximum size limit and includes the recipient's IP address and port.
(4) Receiving datagrams: The recipient listens for incoming datagrams. When a datagram is received, the recipient can extract the contained data and take appropriate actions based on the content.
(5) Closing the socket: At the end of communication, the sender and receiver can close their respective sockets to terminate the UDP connection.

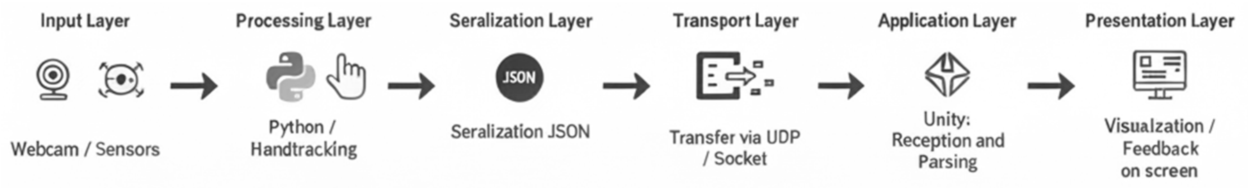


Figure 2: Schematic representation of the Neuroboost system architecture and real-time data pipeline. The flow illustrates the transition from raw sensor input to visual feedback, highlighting the integration between the Python-based hand-tracking environment and the Unity-based visualisation engine via UDP communication. JSON: JavaScript Object Notation; UDP: User Datagram Protocol.

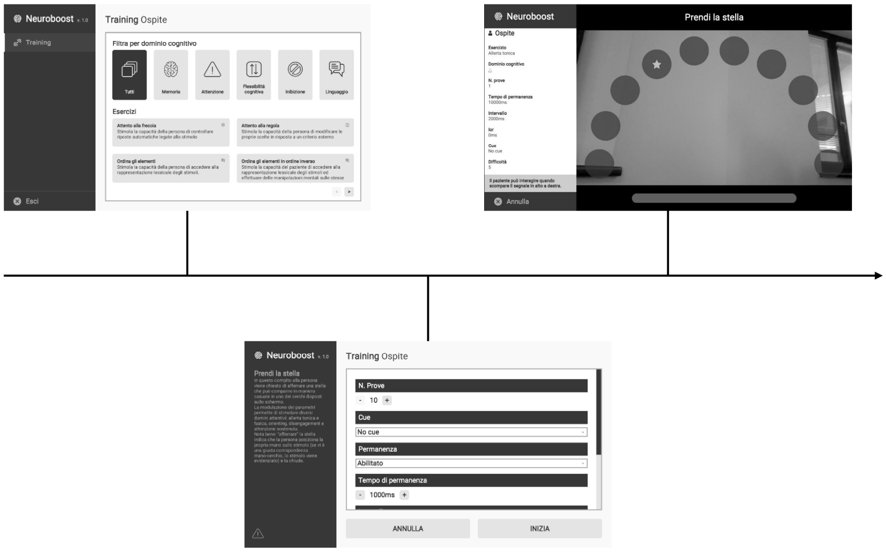
2.3 Privacy

The platform is equipped with the latest "safety parameters" in accordance with the European privacy legislation (see, e.g., the General Data Protection Regulation [GDPR], at https://gdpr-info.eu/, and the Artificial Intelligence Act at https://artificialintelligenceact.eu/). The precautions and strategies adopted to protect the personal data being processed include techniques such as disk encryption, encryption of individual files, encryption of web communications via the HTTPS protocol, and the encryption of databases and backups. Furthermore, data pseudonymization is employed to prevent the association between personal data and sensitive data, while access control is enforced through JSON Web Tokens (JWT) for authentication and authorisation operations. Additionally, in Neuroboost, data are not stored in a permanent database; instead, they are displayed through a pop-up window.

2.4 The Training Module

In Neuroboost, the user can select the cognitive domain to be trained, followed by the specific task and settings (see Fig. 3).

In this initial version of the platform, the user can choose from five domains: memory, attention, inhibition, cognitive flexibility, and language. The exercises designed and developed for each cognitive domain are displayed below. Additionally, for each exercise, the corresponding cognitive domain is indicated in the top right corner. Once an exercise has been selected, the user is directed to the settings screen. Settings vary for each task. Importantly, the modulation of these parameters enables the training of specific aspects of the associated cognitive domain. For example, in the attention task "Catch the Star", selecting the presence or absence of a cue (the illumination of all the circles in the task) allows clinicians to train the phasic or tonic alertness, respectively. Furthermore, the settings screen provides a detailed description of the task, including instructions that the operator provides to the patient to ensure the correct execution of the task. Once the parameters are set, the operator can launch the task by clicking the "Start" button in the bottom right corner. Importantly, the exercises in Neuroboost share the same structure: an arc configuration composed of circles is displayed on the screen.



Attento alla freccia
Stimola la capacità della persona di controllare riposte automatiche legate allo stimolo

Attento alla regola
Stimola la capacità della persona di modificare le proprie scelte in risposta a un criterio esterno

Ordina gli elementi
Stimola la capacità della persona di accedere alla rappresentazione lessicale degli stimoli.

Ordina gli elementi in ordine inverso
Stimola la capacità del paziente di accedere alla rappresentazione lessicale degli stimoli ed effettuare delle manipolazioni mentali sulle stesse

Prendi la stella
In questo compito alla persona viene chiesto di afferrare una stella che può comparire in maniera casuale in uno dei cerchi disposti sullo schermo.
La modulazione dei parametri permette di stimolare diversi domini attentivi: allerta tonica e fasica, orienting, disengagement e attenzione sostenuta.
Nota bene: "afferrare" la stella indica che la persona posiziona la propria mano sullo stimolo (se vi è una giusta corrispondenza mano-cerchio, lo stimolo viene evidenziato) e la chiude.

N. Prove: 10
Cue: No cue
Permanenza: Abilitato
Tempo di permanenza: 1000ms

Esercizio: Allerta tonica
Dominio cognitivo
N. prove: 1
Tempo di permanenza: 10000ms
Intervallo: 2000ms
Ior: 0ms
Cue: No cue
Difficoltà: 5

Il paziente può interagire quando scompare il segnale in alto a destra.

Figure 3: The figure reports, from left to right, the exercise selection screen, settings screen, and the scenario of an attentional task.

The circles presented on the screen can, in certain tasks, be modulated in the settings screen. For example, in the attention task "Catch the Star", in which the patient is asked to identify and grab a target (the star), the number of circles appearing in the scenario—representing locations where the target stimulus might appear—is set by the operator in the settings screen to modulate the complexity of the task itself. Should the user or the patient need to suspend the exercise, they can click the "Cancel" button located in the bottom left of the screen. Once the assigned number of trials for the patient is completed, a summary screen shows the results related to the patient's performance in terms of accuracy and speed (reaction times in ms).

A brief description of the tasks developed in Neuroboost is reported in Table 2 (see also Fig. 4, representative screenshots of the implemented game tasks).

Table 2: The table displays, for each domain. The tasks and their brief description have been reported.

Cognitive Domain	Task	Description
Memory	Repeat the sequence	Memorize a sequence of numbers that light up on the screen during the learning phase. The numbers are shown inside circles arranged in an arc. During this phase, the person memorizes the sequence without performing any movement. Subsequently, the person touches the stimuli in the same order they appeared.
	Repeat the sequence in reverse order.	Memorize a sequence of numbers that light up on the screen during the learning phase. The numbers are shown inside circles arranged in an arc. During this phase, the person memorizes the sequence without performing any movement. Subsequently, the person touches the stimuli in reverse order, starting from the last to the first.

Table 2: *Cont.*

Cognitive Domain	Task	Description
Attention	Catch the star	The person must grab a star that can randomly appear in one of the circles arranged on the screen. Modulation of parameters allows stimulation of different attentional domains, including tonic and phasic alertness, orienting, disengagement, and sustained attention.
Inhibition	Watch out for the arrow	Two circles are placed respectively to the right and left of the person. Arrows appear inside the circles, indicating either left or right. The condition can be congruent, when the arrow points in the same direction as the circle, or incongruent, when the arrow points in the opposite direction to the circle. The person should only grab the arrow in the incongruent condition.
Cognitive Flexibility	Watch out for the rule	Presentation of stimuli that can vary in shape, color, or texture. The person is asked to grab the object that meets the indicated criterion, which varies for each exercise.
Language	Order the elements	Presentation of a sequence of images belonging to different semantic categories. The person must mentally or verbally name the stimuli and then order them alphabetically.
	Order the elements in reverse order	Presentation of a sequence of images belonging to different semantic categories. The person must mentally or verbally name the stimuli and then order them in reverse alphabetical order, from the letter Z to the letter A.

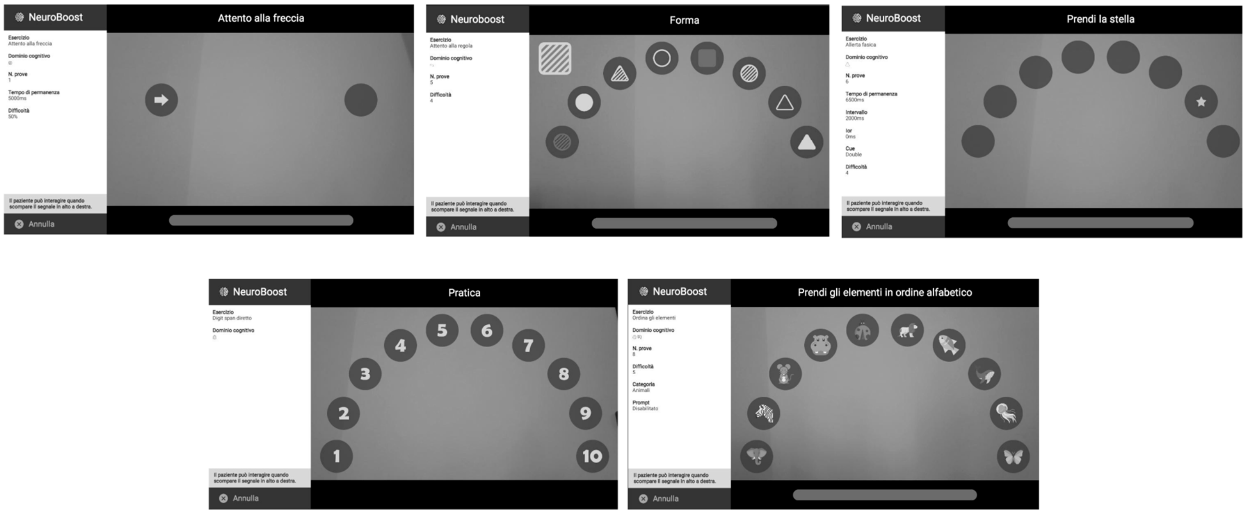


Figure 4: Representative screenshots of the implemented game tasks. The upper panel displays (from left to right): Repeat the Sequence and Repeat the Sequence in Reverse Order, Watch Out for the Rule, and Catch the Star. The lower panel illustrates Order the Elements and Order the Elements in Reverse Order (bottom left) alongside Watch Out for the Arrow (bottom right).

3 Experiment

The aim of this study was twofold: on one hand, we investigated the feasibility, usability, and pleasantness of Neuroboost. On the other hand, we gathered preliminary data on its efficacy in the context of a nursing home.

3.1 Methods

3.1.1 Participants

Due to the exploratory nature of this study, a small sample of four elderly individuals (AB, AS, CL, LB; mean age = 85, SD = 7; mean education level = 6, SD = 3) was recruited. The participants resided at the nursing home of the Neapolisanit Rehabilitation Centre in Ottaviano, Naples. All participants were adequately informed about the study, and their informed consent was obtained. The present study received approval from the Ethical Committee for Psychological Research of the Department of Humanities of the University of Naples Federico II (n° prot. 34/2024), and it was carried out in agreement with the Declaration of Helsinki (2013). Participants exhibited various degrees of motor and cognitive impairment (a pre-training patient assessment is provided in Appendix A). Additionally, as an inclusion criterion, participants were required to possess sufficient ability to understand instructions (equivalent score on the token test [89] score ≥ 2).

3.1.2 Materials

For the present study, a thorough neuropsychological assessment was conducted. The assessed cognitive domains and the tests administered for each domain are summarised in Table 3.

Table 3: The table lists the tests used for each cognitive domain. The acronym and the Italian normative data have been provided in brackets.

Cognitive Domain	Test
Global Cognitive Function	Mini Mental State Examination (MMSE [90,91]) Montreal Cognitive Assessment (MoCA [92])
Visuo-Spatial Memory	Corsi Block-Tapping Test (CBTT [93]) Rey-Osterrieth Complex Figure Test-Delayed Recall (ROCFT_DR [94])
Verbal Memory	Digit Span (DS [93]) Prose Memory (PM [95])
Visuo-Constructive Skills	Constructional Apraxia Test (CAT [89])
Executive Functions	Phonemic Verbal Fluency (PVF [96]) Semantic Verbal Fluency (SVF [89]) Rey-Osterrieth Complex Figure Test-Copy (ROCFT_C [94]) Attentional Matrices (AM [89]) Frontal Assessment Battery (FAB [92])
Logical-Abstract Abilities	Raven's Progressive Matrices (RPM [97])
Mood	Beck Depression Inventory (BDI [98]) Apathy Evaluation Scale (AES [99])
Quality of Life	Quality_VIA (Q_Via [100])

Cognitive stimulation was conducted using Neuroboost. As described above, the platform enabled the provision of cognitive training exercises targeting short-term memory, working memory, language, cognitive flexibility, inhibition, and attention (tonic and phasic alertness, orienting, and disengagement).

Furthermore, an *ad hoc* checklist was created to record the frequency of assistance required by participants (0 = never; 1 = rarely; 2 = moderately frequent; 3 = very frequent; 4 = always present) and to note positive reactions (e.g., the participant shows clear signs of appreciation for the exercises or does not want to stop practicing) or negative reactions (e.g., the participant displays signs of frustration/aggression).

Taken together, data regarding user assistance and participant reactions (both positive and negative) were used to assess usability. The checklist was completed by the examiners. The examiners were social health workers who assisted the patients and were not among the authors of this paper.

3.1.3 Procedure

The patients underwent an initial neuropsychological assessment (T0) preceding the administration of the stimulation protocol. Subsequently, the patients underwent a four-session treatment using Neuroboost. Exercises were administered twice a week for two weeks. Each treatment session lasted a maximum of one hour and aimed to stimulate all cognitive domains targeted by the software. A total of 60 exercises were administered, with approximately ten minutes dedicated to each domain as reported in Table 4.

Table 4: Session details.

Domain	Task	Number of Exercises
Memory	Repeat the sequence	5
	Repeat the sequence in reverse order	5
Attention	Catch the star	30*
Inhibition	Watch out for the arrow	5
Cognitive Flexibility	Watch out for the rule	5
Language	Order the elements	5
	Order the elements in reverse order	5

*For this task ten exercises were carried out for each condition (Tonic and Phasic Alertness and Orienting).

The order of exercise administration was pseudo-randomised for each patient and session using random number generation. Specifically, each task was assigned a numerical code and then sequenced according to a generated random order. Subsequently, the same patients underwent a post-treatment neuropsychological evaluation (T1). The post-treatment neuropsychological assessment was carried out using parallel versions of the abovementioned tests. The neuropsychological assessments and the treatment were administered by two different professionals.

3.2 Data Analysis

Usability data. Descriptive statistics regarding usability were calculated. Specifically, the percentages of help requests for each task across the four training sessions, as well as the percentages of positive and negative reactions to the tasks, were computed.

Performance on Neuroboost's tasks. Given the small sample size (n = 4) and the high risk of Type I errors associated with parametric analyses (e.g., ANOVA), a descriptive approach focused on the visual inspection of data was used to investigate the trends in accuracy percentages across sessions for each domain (Language, Short-term Memory, Working Memory, Inhibition, Cognitive Flexibility, Tonic and Phasic Alertness and Orienting).

Although Neuroboost provides real-time feedback on execution speed, in terms of reaction times (RTs), this dependent variable was excluded from the formal data analysis. The rationale is that in the clinical practice with this specific patient population, the experimental protocol prioritises motor accuracy and functional task completion over execution velocity. Furthermore, in this population, speed may be impaired by motor deficits, which in turn could increase frustration and consequently affect both feasibility and usability. Finally, the scientific literature has highlighted that self-paced cognitive tasks are beneficial for elderly populations, with evidence showing superior learning outcomes and cognitive improvements compared to experimenter-paced or time-pressured conditions [101–103].

Effects of Neuroboost training on neuropsychological test performance. To evaluate whether changes in patients' performance on the neuropsychological tests were statistically and clinically significant, we applied the Reliable Change Index (RCI) to each test across assessment points (T1 vs. T0). The RCI is a psychometric tool designed to determine whether the change in an individual's score over time—specifically, the difference between two measurements—exceeds what could be expected by chance or measurement error. Mathematically, the RCI is calculated as the observed change score divided by the standard error of the difference (SE_{diff}), providing a standardised measure of change. The RCI reflects whether a patient's improvement or decline is statistically significant rather than a product of random fluctuations. The concept of "reliable change" distinguishes true, statistically meaningful changes from those that might result from normal variability in measurement [104–108]. RCI values were computed using the following formula [109]:

$$RCI = (X_{post} - X_{pre})/SE_{diffs}$$

where $SE_{diff} = 2 * \text{SEM}$ and SEM (i.e., standard error of measurement) was derived from normative data validated for the Italian versions of the tests (see Table 3). Because RCI values are essentially standardised z-scores (mean = 0, SD = 1), a value exceeding ±1.96 indicates a statistically significant change at the 95% confidence level, corresponding to the conventional threshold for reliable change.

Separate RCIs were collected for each participant.

However, since this is a pilot study designed to evaluate the feasibility of the protocol and given the small sample size, we suggest that the results should be interpreted with caution.

3.3 Results

3.3.1 Usability Data

The results regarding usability showed that help requests were frequent across all tasks (Fig. 5), but they were more likely to occur in tasks training cognitive flexibility (88%), inhibition (100%), and both short-term memory (100%) and working memory (100%).

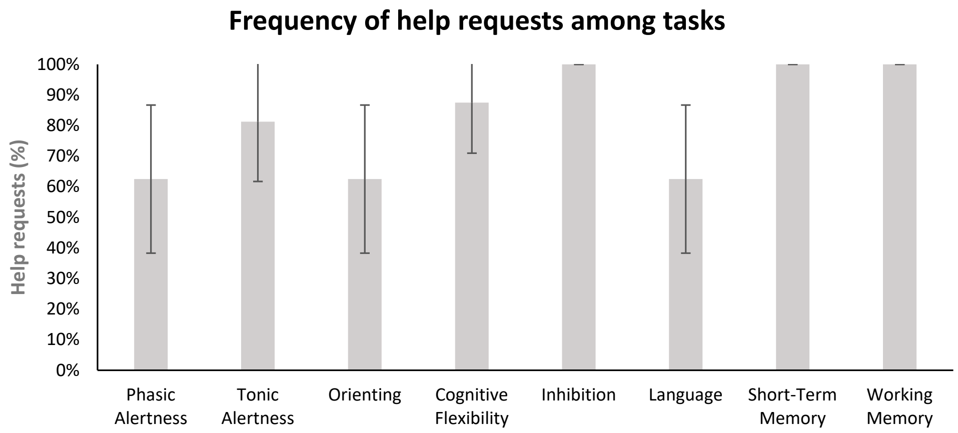


Figure 5: Frequency, in percentage, of help requests from participants for each task. Error bars depict the standard error of the proportion.

However, requests for help decreased over the sessions, indicating increased practice and familiarity with the platform (Fig. 6). These data suggest evidence of the "learnability" of the software, namely the extent to which new users can quickly and easily understand, navigate, and efficiently perform tasks within a system upon their initial and early encounters.

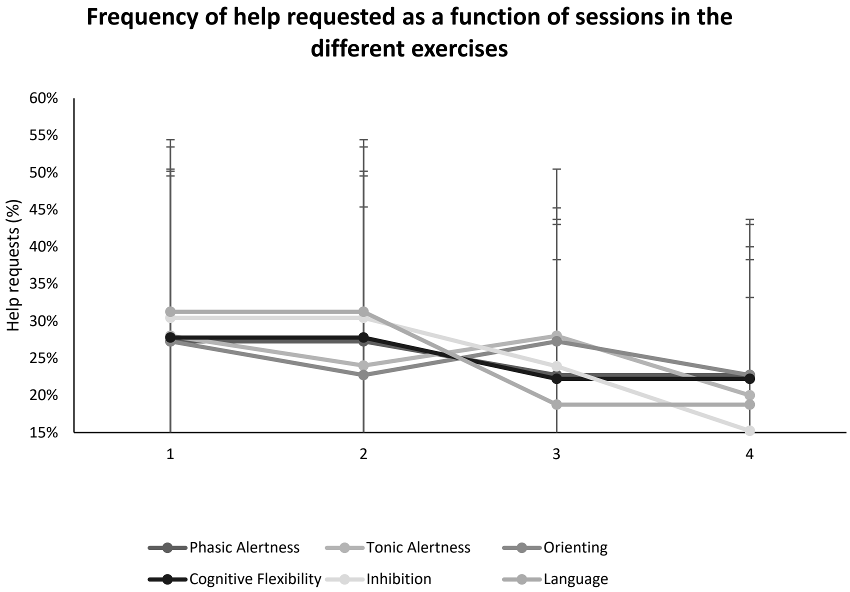


Figure 6: Frequency, in percentage, of help requests from participants for each task as a function of the training sessions. Error bars depict the standard error of the proportion.

Finally, the assessment of pleasantness showed that the participants appreciated the platform and its games, displaying a higher frequency of positive reactions compared to negative ones (Fig. 7).

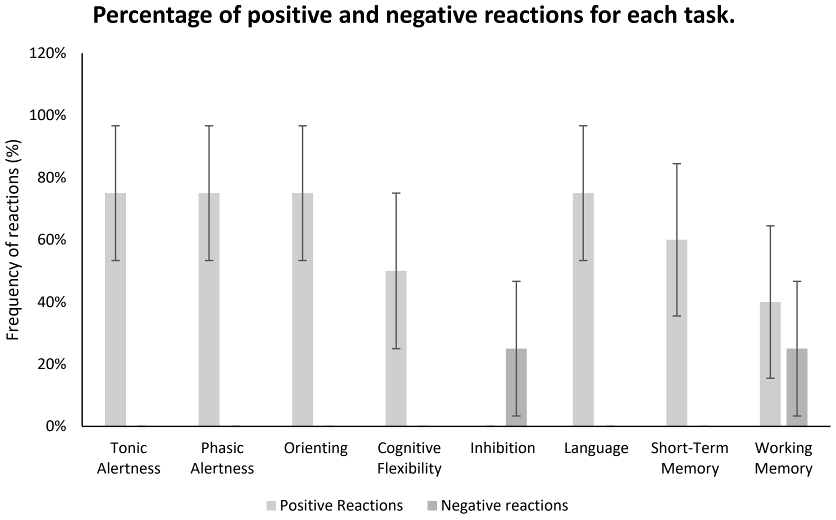


Figure 7: Positive and negative reactions for each task have been reported. Error bars depict the standard error of the proportion.

3.3.2 Performance on Neuroboost Tests

The visual inspection of the data revealed an increase in accuracy as a function of the number of sessions (Fig. 8).

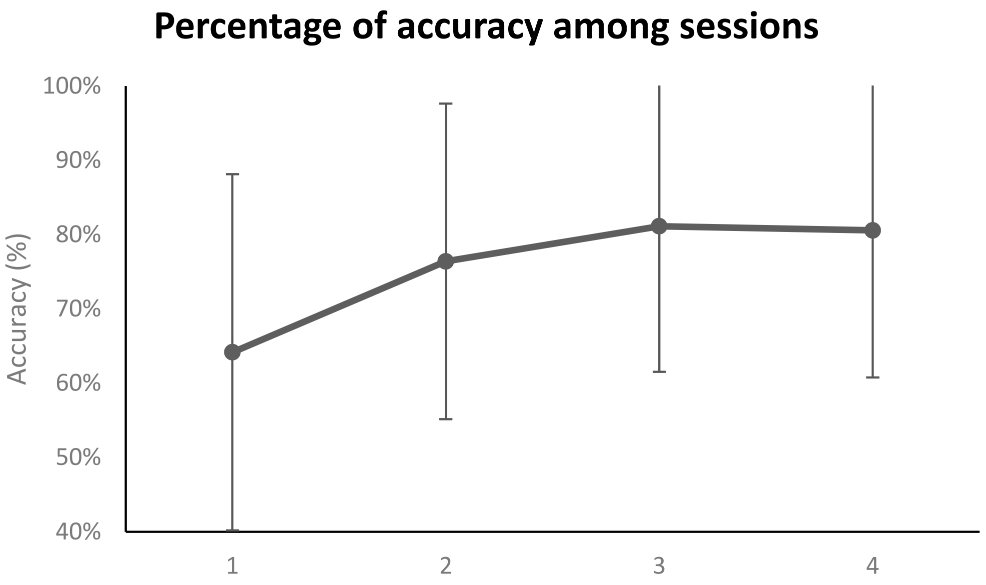


Figure 8: The percentage of accuracy among sessions has been reported. Error bars depict the standard error of the proportion.

This result was consistent among the tests, as shown in Table 5.

Table 5: The table shows the accuracy in the different domains trained through neuroboost among sessions.

	Session			
Domain	**1**	**2**	**3**	**4**
Short-Term Memory	60%	60%	65%	65%
Working Memory	50%	60%	55%	55%
Tonic Alertness	88%	98%	95%	100%
Phasic Alertness	93%	100%	100%	98%
Orienting	88%	95%	95%	93%
Cognitive Flexibility	80%	80%	80%	85%
Inhibition	0%	20%	55%	45%
Language	60%	85%	93%	95%

Changes in accuracy across different tests were also investigated in individual patients.

The results showed that, overall, patients improved their performance in terms of accuracy across the various sessions. This result was consistent even when considering the performance of individual patients (Fig. 9). Specifically, patients reached an 80% accuracy threshold, with the exception of patient AS.

Table 6, instead, reports the performance of individual patients in terms of percentages across sessions for each domain.

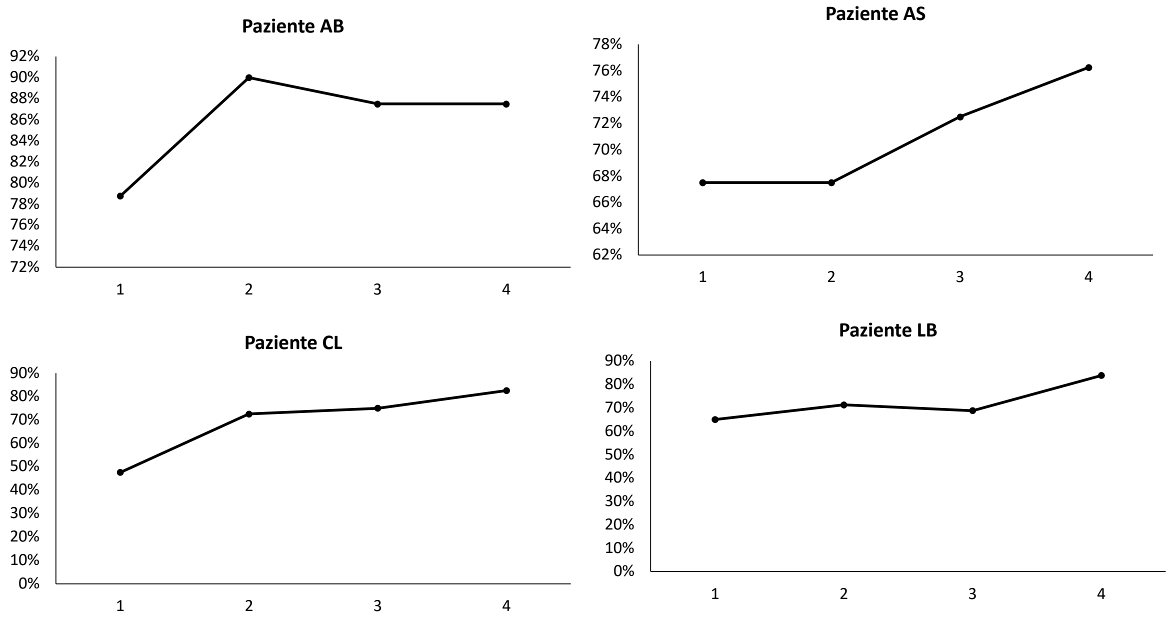


Figure 9: The figure shows the changes in patient performance in terms of accuracy percentage across different training sessions.

Table 6: For each patient, the changes in each session are reported in terms of accuracy percentage. The performance refers to the individual domains stimulated through Neuroboost.

Patient	**LB**				**AB**				**CL**				**AS**			
Session	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Domain																
Short-term memory	60%	40%	60%	60%	80%	80%	80%	60%	40%	60%	40%	60%	60%	60%	80%	80%
Working memory	60%	80%	60%	40%	60%	80%	60%	60%	20%	40%	40%	60%	60%	40%	60%	60%
Tonic alertness	80%	90%	90%	100%	100%	100%	100%	100%	70%	100%	100%	100%	100%	100%	90%	100%
Phasic alertness	90%	100%	100%	100%	100%	100%	100%	100%	80%	100%	100%	100%	100%	100%	100%	90%
Orienting	90%	80%	100%	90%	100%	100%	100%	100%	60%	100%	100%	100%	100%	100%	80%	80%
Cognitive flexibility	80%	100%	100%	60%	100%	100%	80%	80%	80%	80%	80%	100%	60%	60%	60%	80%
Inhibition	0%	0%	0%	60%	0%	60%	80%	100%	0%	0%	40%	40%	0%	20%	40%	40%
Language	65%	71%	84%	69%	90%	100%	100%	100%	30%	100%	100%	100%	60%	60%	70%	80%

3.3.3 Effects of Neuroboost Training on Neuropsychological Test Performance

Table 7 reports the pre- and post-training performance for the three patients (AB, CL, and LB), along with the Reliable Change Index (RCI) for each measure. One patient (AS) was excluded from the final analysis due to failure to complete the neuropsychological assessment at T1.

Global Cognition. LB showed a significant gain on the MMSE (RCI = 2.95). This gain was not observed in AB and CL. Both LB and CL exhibited an improvement close to the threshold on the MoCA. AB did not exhibit a significant gain in either MMSE and MoCA.

Table 7: The table shows the difference of performance between the pre- and post-treatment assessment and the relative RCI Index. Asterisks highlight the significant results.

Patient		**AB**			**CL**			**LB**		
Domain	**Test**	**T0**	**T1**	**RCI Index**	**T0**	**T1**	**RCI Index**	**T0**	**T1**	**RCI Index**
Global cognition	MMSE	27	27	0.00	20	20	0.00	26	27	2.95*
	MoCA	21	22	0.41	12	15	1.24	16	20	1.65
Executive functions	FAB	13	16	1.75	8	10	1.17	15	14	−0.58
	ROCFT_C	31	27	−1.23	10	8.5	−0.46	15	18	0.92
	AM	39	37	−0.46	33	25	−1.82	7	12	1.14
	RPM	21	22	0.37	14	17	1.12	17	15	−0.74
Memory	CBTT	5	5	0.00	4	4	0.00	4	4	0.00
	ROCFT_DR	8	3.5	−1.67	1	4	1.12	5	4	−0.37
	DS	6	5	−1.29	4	4	0.00	5	5	0.00
	PM	12	20	2.57*	13	20	2.25*	11	21	3.21*
Visuoconstruction	CAT	12	10	−0.29	4	5	0.15	10	10	0.00
Language	PVF	20	30	2.87*	5	11	1.72	13	18	1.44
	SVF	14	14	0.00	9	11	0.22	14	14	0.00
Mood	BDI	20	24	1.01	35	35	0.00	13	5	−2.02*
	AES	48	41	−2.12*	56	51	−1.51	37	23	−4.23*
Quality of life	VIA_Tot	60	113	23.42*	86	101	6.63*	80	107	11.93*
	VIA_C	5	12	7.61*	7	9	2.18*	8	12	4.35*
	VIA_E	14	20	5.98*	20	20	0.00	14	19	4.98*
	VIA_R	4	14	10.71*	10	10	0.00	9	12	3.21*
	VIA_A	6	11	4.16*	8	12	3.33*	6	11	4.16*
	VIA_P	16	27	8.10*	20	25	3.68*	18	21	2.21*
	VIA_SC	11	19	5.10*	14	15	0.64	17	21	2.55*
	VIA_AS	4	10	5.81*	7	10	2.91*	8	11	2.91*

MMSE: Mini Mental State Examination; MoCA: Montreal Cognitive Assessment; FAB: Frontal Assessment Battery; CBTT: Corsi Block-Tapping Test; ROCFT_DR: Rey-Osterrieth Complex Figure Test_Delayed Recall; DS: Digit Span; PM: Prose Memory; CAT: Constructional Apraxia Test; ROCFT_C: Rey-Osterrieth Complex Figure Test _Copy; PVF: Phonological Verbal Fluency; SVF: Semantic Verbal Fluency; AM: Attentional Matrices; RPM: Raven's Progressive Matrices; BDI: Beck Depression Inventory; AES: Apathy Evaluation Scale; Q_VIA Tot: Quality via Total Score; VIA_C: Care Services VIA's Subscale; VIA_E: Environmental Satisfaction VIA's Subscale; VIA_R: Relationship with the Caregiving Staff VIA's Subscale; VIA_A: Activity VIA's Subscale; VIA_P: Privacy and Self-Determination VIA's Subscale; VIA_SC: Social Cohesion and Sense of belonging VIA's Subscale; VIA_AS: Self-Fulfillment/Spirituality VIA's Subscale. Asterisks highlight the significant comparisons. *$p < 0.05$.

Executive Functions. Performance on executive tasks showed mixed results. AB showed a gain on the FAB approaching significance (RCI = 1.75), whereas LB showed a small decline (RCI = −0.58). The copy performance on the ROCFT showed a slight decline for AB (RCI = −1.23), whereas LB showed a modest improvement (RCI = 0.92). These changes did not reach significance. Additionally, performance on Raven's Progressive Matrices was not significant.

Memory. A significant improvement was found in Prose Memory (PM) across all three patients (AB: RCI = 2.57; CL: RCI = 2.25; LB: RCI = 3.21). In contrast, delayed recall on the ROCFT showed heterogeneous trajectories: CL improved reliably (RCI = 1.12), while AB displayed a decline (RCI = −1.67). No reliable changes emerged for LB. Scores revealed no reliable improvements on the CBTT or Digit Span across any of the patients.

Visuoconstruction. No reliable change was observed in the Constructional Apraxia Test (CAT).

Language and Fluency. A reliable improvement was observed for phonological verbal fluency (PVF), with AB showing the largest individual gain (RCI = 2.87). No patient showed reliable changes in semantic fluency (SVF).

Affective and Motivational Measures. A decrease in depressive symptoms (BDI) was observed only for LB (RCI = −2.02), whereas AB showed a mild increase (RCI = 1.01). In contrast, apathy scores (AES) showed a significant reduction, with all patients showing reliable or near-reliable decreases (most notably LB, RCI = −4.23).

Quality of Life (VIA). Interestingly, the most consistent and robust effects emerged across the VIA quality-of-life scales. Total VIA scores increased reliably, with all patients exhibiting significant improvements (AB RCI = 23.42; CL RCI = 6.63; LB RCI = 11.93). Significant gains were also observed in several VIA subscales, including Care Services (VIA_C), Environmental Satisfaction (VIA_E), Relationships with Staff (VIA_R), and Activities (VIA_A)—which were significant for AB and CL—as well as Privacy/Self-determination (VIA_P), Social Cohesion (VIA_SC) (significant for AB), and Self-fulfillment/Spirituality (VIA_AS), with reliable improvements across all patients.

Taken together, the results showed that the intervention was associated with selective improvements in global cognition, memory, verbal fluency, mood, and quality-of-life measures, whereas changes in executive functions and visuoconstructional abilities were more heterogeneous. However, due to the lack of a control group, these improvements cannot be unequivocally attributed to Neuroboost, and caution should be exercised when generalising these results.

3.4 Discussion

The development and application of exergames for cognitive and motor rehabilitation have gained significant attention in recent years [84,86,110,111]. Computerised cognitive interventions utilising this technology have demonstrated utility in addressing limitations associated with traditional serious games, such as excessive sedentary behaviour, while simultaneously fostering more dynamic and engaging cognitive rehabilitation programs. However, the increment of exergames has not consistently been supported by studies evaluating their validity, effectiveness, and clinical relevance. Moreover, many existing interventions rely on commercially available platforms (e.g., Xbox Kinect [38,112,113]) that were neither designed specifically for clinical populations nor adequately tailored to operationalise cognitive constructs. As a result, these tools often serve as generic training programs originally developed for entertainment rather than therapeutic purposes.

In this study, we introduced Neuroboost, a platform specifically designed for motor-cognitive rehabilitation across different clinical populations. The tasks embedded in Neuroboost were carefully developed through the precise operationalisation of cognitive processes—such as attention, memory, executive functions, and language—drawing upon validated neuropsychological tests (e.g., the Attention Network Test-Revised for attention tasks [114]). Beyond its design and development, Neuroboost underwent a pilot evaluation to assess both its feasibility and usability, with a particular emphasis on user engagement and ease of use.

The findings of this study provide preliminary evidence supporting the feasibility of the Neuroboost platform. Specifically, systematic training conducted over two weeks (two sessions per week) with institutionalised elderly individuals suggested: (1) direct benefits, including improvements in accuracy on Neuroboost-administered tasks and in specific cognitive domains assessed through the standardised neuropsychological assessments; and (2) indirect benefits, specifically an improvement in quality of life and mood. Regarding direct benefits, the data obtained in the present study are consistent with the observation by Swinnen et al. [115]. In their study, the authors investigated the effects of an exergame-based intervention in patients with major neurocognitive deficits residing in a nursing home. The results showed that after an eight-week intervention program (three sessions per week), the elderly in the experimental group demonstrated higher scores in motor (walking speed), cognitive (global functioning), and mood-related domains.

Notably, the improvements in quality of life identified in this study represent an area of divergence from some existing literature. For example, in their systematic literature review, Van Santen et al. [116] reported that exergames were associated with significant improvements in motor, cognitive, and emotional functioning, but not in quality of life. In the present study, the improvement in the quality of life could stem from two factors: (1) the interaction with examiners during training sessions, which may have provided participants with a platform to express emotions, discuss challenges, and assume a central role in the therapeutic process; and (2) perceived improvements in cognitive functioning, which may have bolstered self-efficacy and self-esteem, thereby indirectly enhancing overall quality of life. In our study, two out of three patients (AB and LB) reported a marked increase in the Quality_VIA subscale "Relationship with the caregiving staff", supporting the idea that the improvements in quality of life may stem from social interaction, especially among institutionalised elderly individuals. This is consistent with the scientific literature reporting that institutionalised elderly individuals often exhibit a lower mean quality of life score, particularly regarding social relationships [117] within the nursing home context [118]. In fact, Chruściel and colleagues [118], in their research, reported that the quality of life was linearly correlated with social support. Consistent with this core finding, future technological design and development in this field should focus not only on stimulating functional rehabilitation but also on fostering social interaction [119–122]. For example, Li and colleagues [119] conducted comprehensive interviews in a Dutch nursing home and designed three interactive systems specifically targeting social interaction and well-being. The authors highlighted that technological design and development in institutional care settings should focus on fostering social engagement, as highlighted by the development of interactive systems based on qualitative research with residents and caregivers.

Usability assessments indicated initial challenges in navigating the platform, necessitating frequent assistance from facilitators. However, as participants became familiar with the platform, requests for help declined, reflecting a learning curve and growing comfort with the system. These data provide evidence regarding the system's 'learnability', namely the degree to which novice users can intuitively navigate the interface and execute tasks effectively during their initial interactions. This core finding is consistent with the emerging literature in which the focus is on both effectiveness and learnability outcomes [123–125] even though significant "room for improvement" [126] remains, especially for people with dementia who often face significant difficulties in learning to use technological platforms [127]. For example, Bermúdez and colleagues [128] reported that their sample of institutionalised elderly participants found a mixed reality exergaming platform engaging and enjoyable, with positive reactions outweighing negative ones, as it improved their quality of life and social relations.

Furthermore, evaluations of pleasantness revealed that participants found the platform engaging and enjoyable, with positive reactions outweighing negative ones. This evidence is consistent with several studies demonstrating that institutionalised elderly participants find technology platforms engaging and enjoyable, with positive emotional responses outweighing negative ones [129–132], especially when engaged in exergames [128,133].

In conclusion, the preliminary data presented here suggest that Neuroboost is a promising platform for cognitive stimulation and rehabilitation in institutionalised elderly populations. It demonstrates potential to improve both cognitive functioning and quality of life, making it a valuable tool for addressing the multifaceted needs of this demographic. Further studies with larger sample sizes and longer follow-up periods are warranted to substantiate these findings and optimise the platform's usability and efficacy.

3.5 Limitation and Future Perspective

This study presents preliminary findings from a larger ongoing research project. However, despite the promising nature of these results, the following limitations should be considered: (1) a small sample size (n = 4); (2) the lack of a control group; (3) the short duration of the intervention; and (4) the absence of long-term follow-up data.

Future work will address the aforementioned limitations by: (1) expanding the sample size through the recruitment of additional facility residents; (2) involving a control group; (3) increasing the duration of the intervention; and (4) providing follow-up assessments of neuropsychological functions, mood, and quality of life. Specifically, participants will initially engage in entertainment activities organised by a community animator, followed by neuropsychological reevaluation to assess the stability of observed effects over time. In other words, future studies will aim to enhance the generalizability of our results and tests whether cognitive and quality-of-life improvements remain stable or decrease without systematic treatment.

Regarding Neuroboost, several updates are currently under development to enhance its utility and effectiveness. These updates include: (1) expanding the range of training exercises to provide greater variability and engagement; (2) designing and implementing exercises tailored to individual cognitive profiles, enabling the creation of personalised intervention plans based on initial assessments; and (3) introducing a "statistics" section to record and track participants' performance over time, facilitating detailed progress monitoring and data analysis.

These advancements are expected to further refine Neuroboost's capacity as a tool for delivering effective and individualised cognitive-motor rehabilitation while promoting sustained improvements in quality of life for clinical populations.

4 Conclusions

The present study introduced Neuroboost, an innovative exergame platform that aims to merge physical hand movements with cognitive stimulation. The preliminary findings from this pilot study show that Neuroboost is a feasible tool for institutionalised elderly individuals, including those with cognitive and motor impairments. Specifically, the results indicate that while participants initially required assistance, their autonomy and engagement increased across the sessions. Furthermore, the data suggest that the platform effectively targets specific neuropsychological domains while improving psychological well-being by reducing apathy and enhancing mood.

In conclusion, although the study is limited by a small sample size, the results provide preliminary evidence about the use of exergames in geriatric care.

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Availability of Data and Materials: Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

Ethics Approval: The present study received the approval of the Ethical Committee of Psychological Research of the Department of Humanities of the University of Naples Federico II (n° prot. 34/2024) and it was carried out in agreement with the declaration of Helsinki (2013). All participants were adequately informed about the study, and their informed consent was obtained.

Conflicts of Interest: Raffaele Nappo is a part-time employee of the Neapolisanit Rehabilitation Center, which also provided funding for this study. The authors affirm that they have no additional financial or personal conflicts of interest that could have influenced the work reported in this manuscript.

Appendix A

Table A1: Demographic and Neuropsychological Profiles of the Patient Cohort.

Patients		AB			AS			CL			LB		
Domain	**Demographi/Test**	**Raw Score**	**Correct Score**	**Equivalent Score**	**Raw Score**	**Correct Score**	**Equivalent Score**	**Raw Score**	**Correct Score**	**Equivalent Score**	**Raw Score**	**Correct Score**	**Equivalent Score**
Demographic	**Age**	75			87			92			86		
	Education	8			5			1			8		
	Diagnosis	Ischemic heart disease, Parkinson's disease			Prostate cancer, hypertensive heart disease, chronic cerebral vasculopathy			Ischemic stroke			Colon cancer		
Global cognition	**MMSE**	27	28.2	Normal	18	20.03	Pathological	20	25.24	Normal	26	27.2	Normal
Global cognition	**MoCA**	21	23.72	4	9	14.33	0	12	19.69	2	16	19.66	2
Executive fuctions	**FAB**	13	13.9	1	4	6.2	0	8	13.9	1	15	16.7	4
Memory	**CBTT**	5	4	1	4	4.5	3	4	4.75	4	4	4.75	4
Memory	**ROCFT_DR**	8	11.75	2	1	7	0	1	11.5	2	5	14.5	3
Memory	**DS**	6	6.25	4	4	4.8	3	4	5.1	4	5	5.25	4
Memory	**PM**	12	11.45	2	5	6.25	1	13	14.7	4	11	11.8	3
Visuoconstruction	**CAT**	12	12.25	3	9	10.25	2	4	10.25	2	10	11	2
Executive fuctions	**ROCFT_C**	31	33.25	4	23	26.25	0	10	13.75	0	15	18.75	0
Language	**PVF**	20	24.7	2	1	11.4	0	5	15.4	0	13	18.7	1
Language	**SVF**	14	16	3	8	12	2	9	14.25	2	14	17.25	4
Executive functions	**AM**	39	40	2	17	23.25	0	33	25.75	0	7	13.25	0
Executive functions	**RPM**	21	26.5	2	9	16	0	14	22.5	1	17	22.5	1
Autonomy	**ADL***	2/6	-	-	4/6		-	5/6	-	-	3/6	-	-
Autonomy	**IADL***	2/5	-	-	2/8		-	4/5	-	-	6/8	-	-
Mood	**BDI**	20	-	Pathological	13	-	Lower limits of normal	35	-	Pathological	13	-	Lower limits of normal
Mood	**AES**	48	-	Pathological	38	-	Lower limits of normal	56	-	Pathological	37	-	Lower limits of normal
Quality of life	**VIA_Tot**	60	-	Not satisfied	122	-	Normal	86	-	Normal	80	-	Normal
Quality of life	**VIA_C**	5	-	Not satisfied	14	-	Normal	7	-	Not satisfied	8	-	Normal

Table A1: *Cont.*

Patients		**AB**			**AS**			**CL**			**LB**		
Domain	**Demographi/Test**	**Raw Score**	**Correct Score**	**Equivalent Score**	**Raw Score**	**Correct Score**	**Equivalent Score**	**Raw Score**	**Correct Score**	**Equivalent Score**	**Raw Score**	**Correct Score**	**Equivalent Score**
Quality of life	**VIA_E**	14	-	Normal	20	-	Normal	20	-	Normal	14	-	Normal
Quality of life	**VIA_R**	4	-	Not satisfied	16	-	Normal	10	-	Normal	9	-	Normal
Quality of life	**VIA_A**	6	-	Normal	12	-	Normal	8	-	Normal	6	-	Normal
Quality of life	**VIA_P**	16	-	Not satisfied	22	-	Normal	20	-	Normal	18	-	Normal
Quality of life	**VIA_SC**	11	-	Normal	23	-	Normal	14	-	Normal	17	-	Normal
Quality of life	**VIA_AS**	4	-	Not satisfied	15	-	Normal	7	-	Not satisfied	8	-	Normal

Notes: 0: pathological score; 1: lower limits of normal; 2-4: normal score; *value without normative reference. MMSE: Mini Mental State Examination; MoCA: Montreal Cognitive Assessment; FAB: Frontal Assessment Battery; CBTT: Corsi Block-Tapping Test; ROCFT_DR: Rey-Osterrieth Complex Figure Test_Delayed Recall; DS: Digit Span; PM: Prose Memory; CAT: Constructional Apraxia Test; ROCFT_C: Rey-Osterrieth Complex Figure Test _Copy; PVF: Phonological Verbal Fluency; SVF: Semantic Verbal Fluency; AM: Attentional Matrices; RPM: Raven's Progressive Matrices; BDI: Beck Depression Inventory; AES: Apathy Evaluation Scale; Q_VIA Tot: Quality via Total Score; VIA_C: Care Services VIA's Subscale; VIA_E: Environmental Satisfaction VIA's Subscale; VIA_R: Relationship with the Caregiving Staff VIA's Subscale; VIA_A: Activity VIA's Subscale; VIA_P: Privacy and Self-Determination VIA's Subscale; VIA_SC: Social Cohesion and Sense of belonging VIA's Subscale; VIA_AS: Self-Fulfillment/Spirituality VIA's Subscale.

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