Participation of children and youth with acquired brain injury

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Chapter 7
Gaming supports youth with acquired brain injury? A pilot study

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ABSTRACT

Aim To explore the effects of usage of the Nintendo Wii on physical, cognitive and social functioning in patients with acquired brain injury (ABI).

Methods This multicentre, observational proof-of-concept study included children, adolescents and young adults with ABI aged 6-29 years. A standardized, yet individually tailored 12-week intervention with the Nintendo Wii was delivered by trained instructors. The treatment goals were set on an individual basis and included targets regarding physical, mental and/or social functioning. Outcome assessments were done at baseline and after 12 weeks, and included: the average number of minutes per week of recreational physical activity; the CAPE (Children's Assessment of Participation and Enjoyment); the ANT (Amsterdam Neuropsychological Tasks); the achievement of individual treatment goals (Goal Attainment Scaling); and quality of life (PedsQL; Paediatric Quality of Life Inventory). Statistical analyses included paired t-tests or Wilcoxon-Signed-Rank tests.

Results Fifty patients were included, (31 boys and 19 girls; mean age 17.1 years (SD 4.4)), of whom 45 (90%) completed the study. Significant changes of the amount of physical activity, speed of information processing, attention, response inhibition and visual-motor coordination ($p<0.05$) were seen after 12 weeks, whereas there were no differences in CAPE or PedsQL scores. Two-thirds of the patients reported an improvement of the main treatment goal.

Conclusion This study supports the potential benefits of gaming in children and youth with ABI.

INTRODUCTION

The incidence of acquired brain damage (ABI) in people aged up to 25 years old in the Netherlands is substantial, with about 19 000 new cases per year[1,2.] International incidence rates for traumatic brain injury in the age group 0-14 years vary, due to differences in definition, inclusion criteria and methodology, from 280[3] to 798[4] per 100 000 persons per year.

Patients with ABI experience motor problems as well as cognitive, behavioural and emotional limitations. These consequences often have a significant and long-standing impact on activities of daily living and participation in society, such as difficulty in achieving and maintaining employment and social relationships.[5,6,7] Moreover, it was found that young patients with ABI are less involved in leisure activities than their peers, their activities are more passive, home-based and lack variety.[5] Patients have labelled social isolation as their most disabling limitation in activities and participation and as their major problem.[8,9]

Regarding the effectiveness of rehabilitation of children and youth with ABI, systematic reviews[10,11] concluded that the evidence for the effectiveness of interventions to treat neurocognitive sequelae is sparse. Interventions that proved to be effective in individual clinical studies included the ATAG (Amsterdam Trainingsprogramma Aandacht Geheugen voor kinderen; Training program Attention and Memory for children),[12] a structured and attractive program of 20 weeks daily training of sustained, focused attention, mental tracking and memory, and the SARAH-program,[13] a family based program, focused on improving family problem solving, relationships and associated child's behaviour.

In addition to conventional rehabilitation strategies, virtual reality (VR) and gaming, especially commercial 'off the shelf' consoles, are more and more acknowledged to be promising therapeutic interventions to improve learning and performance of motor skills in patients with ABI.[14] Recently, two systematic reviews evaluating the effects of virtual reality and interactive video gaming in patients after stroke were published.[15,16] One review[15] included 5 randomized clinical trials and 7 observational studies with 11 of the 12 studies showing a benefit of virtual reality for selected outcome. The other review[16] found limited evidence that the use of virtual reality and interactive video gaming may be beneficial in improving arm function and Activities of Daily Living (ADL) function when compared with the same dose of conventional therapy. Moreover, insufficient evidence was found for the effectiveness of virtual reality and interactive video gaming on grip strength or gait speed. The latter review also concluded that there are few studies evaluating the use of commercial gaming consoles, such as the Nintendo Wii. In the two reviews, two studies using the Nintendo Wii were included,[17,18] both reporting positive effects on motor functioning. A recent study published after the inclusion period of the 2 aforementioned reviews found a significant improvement in static and dynamic balance using easy Balance Virtual Rehabilitation (eBaViR), a system

based on the Wii Balance Board, in adult patients with ABI including stroke.[19] Specifically in children and youth with ABI the potential effectiveness of the Nintendo Wii on visual-perceptual processing, postural control, and functional mobility was described in a case series including adolescents and children with cerebral palsy.[20]

In conclusion, the currently available literature suggests that the available studies on the Nintendo Wii in ABI are sparse, have mainly focused on motor outcome measures, adults, and count small samples. The aim of the present study was therefore to explore the effect of the usage of the Nintendo Wii in children, adolescents and young adults with ABI on variables effecting body functions, activities, participation and overall quality of life. Being a proof-of-concept study, we hypothesized that gaming with the Wii may have a positive effect on physical, cognitive and social functioning in this patient group.

PATIENTS AND METHODS

Design

This multicentre, observational study was carried out from February to June 2010 in three centres in the Netherlands (Sophia Rehabilitation, The Hague; De Hoogstraat Rehabilitation, Utrecht and Mariendael, Arnhem). These centres provide rehabilitative services and/or special education for children and youth with physical disabilities and chronic diseases.

Patients who were eligible for the study were invited by their medical specialist to participate in the study. If they were interested, they received information from one of the therapists or teachers who were involved in the project. After this introduction, all patients / students and their parents (patients under the age of 16 years) received an information leaflet about the project. This study was approved by the medical ethical committee of the Leiden University Medical Centre. All participants / patients gave written informed consent. In addition, all participants signed a contract for the loan of a Nintendo Wii set for the duration of the study.

Patients

Inclusion criteria were: Having ABI according to the Diagnosis Treatment Combination-coding of the medical registries of Sophia Rehabilitation, De Hoogstraat or Mariendael, with the diagnosis verified by their treating rehabilitation specialist; age from 6 to 29 years; and being a patient or a student at the time of inclusion in one of the participating institutions.

Fifty-eight children, adolescents and young adults, registered as patient or student in one of the three centres, were informed about the study and received general information. Fifty-one of them showed interest and were invited for the screening. All 51 patients were found to be eligible for the study. After the screening one patient declined participation, so that 50 patients were finally included.

Excluded were patients who: would not be able to play with the Nintendo Wii due to e.g. lack of coordination, poor physical or mental condition; had a risk of falling due to insufficient balance and/or inadequate motor response; had excessive disinhibition (sensory or behavioural); or had impaired sensory processing (visual-auditory disruption), as judged by the treating rehabilitation specialist.

Intervention

The 12-week intervention consisted of two training sessions (60 minutes each) regarding the use of the Nintendo Wii, delivered by a trained physical therapist, occupational therapist or a teacher from the special school which participated in the study. Assessments were conducted before (baseline) and directly after the intervention (follow-up at 12 weeks).

At the first training session, an inventory of the participant's three main limitations regarding their daily functioning was made by means of the 'personal profile', a semi-structured interview comprising the following domains: gross motor activities (seven categories) and fine motor activities (five categories), information processing (three categories), communication (six categories), self-confidence, social participation and daily physical activity (each one category).

Subsequently, three Nintendo Wii games were assigned, matching the individual treatment goals and by taking into account the individual's motor and cognitive limitations and interest. This was done by using a fixed, digital protocol, which was called TherapWii (available at www.TherapWii.nl). This protocol included a list of common treatment goals in patients with ABI which are linked to 16 different Nintendo Wii games, each game consisting of several sub-games. For example, the goal "improving balance" was linked to six games (i.e. Wii Fit, Sports, Sports Resort, EA Sports, Samba de Amigo and Kororinpa), more specifically to 57 sub-games (e.g. Single Leg Extension and Ski Jump of the game Wii Fit). The protocol was developed by an expert group including four physical therapists, two occupational therapists, two teachers and two neuropsychologists, all with ample experience in the treatment of children and youth with ABI. After the first training session the participant was able to connect and start the console, create a personal profile and play the three assigned games (including activities such as searching in the menu, playing together, using different controllers). Safety instructions (exercise area, strap, balance) were given as well as individual advice tailored to the therapist's or teacher's estimation of the risk on sensory or behavioural loss of control. All participants were encouraged to play the assigned games each for at least 20 minutes per week and to play in total two hours per week (at home, at school or during an individual rehabilitation session in rehab). Playing games other than the three assigned games was permitted. At the second training session, scheduled at about six weeks after the first, the progression was evaluated, and instructions on the use of the three assigned games or additional games were provided. During the 12-week intervention period,

therapists and teachers had weekly contact with the participants by e-mail or telephone. In addition, they sent a text message to the participants' cell phone every week as a reminder to play.

Assessment methods

Assessments were done by the six therapists and teachers delivering the intervention, and two neuropsychologists/psychometrics who performed the neuropsychological tests. Before the start of the study, all professionals took part in a training session on the execution of the various measurements. Assessments were done at baseline (before the first treatment session) and 12 weeks thereafter.

Sociodemographic and disease characteristics

Sociodemographic data were gathered by means of a semi-structured interview. Data on disease history and severity were obtained from medical records. Sociodemographic characteristics included: age (years), sex (male/female), work status (yes/no/not applicable), school type (level/not applicable), special school (yes/no/not applicable), experience with gaming (yes/no; if yes: experience with Wii yes/no).

Disease characteristics comprised: cause of ABI (traumatic or non-traumatic) and time since diagnosis (< 1 year, between 1-2 years, 2-3 years, 3-4 years, > 4 years). In addition, it was recorded whether patients currently received therapy (yes/no) and if they were using an assistive device (yes/no).

Adherence with the intervention

Adherence to the intervention was measured by recording the participants' attendance to the two training sessions.

Physical, recreational and social activity

Outcome measures of physical, recreational and social activity included a single question on physical activity and a multidimensional questionnaire.

Time spent on physical activity: All participants estimated the time spent on physical activities over the past week on a 4 point scale: 1: 0-29 minutes, 2: 30-59 minutes, 3: 60-119 minutes, and 4: 120 minutes or more.

CAPE (Children's Assessment of Participation and Enjoyment), a questionnaire which was developed in Canada, measuring self-reported participation in recreation and leisure activities outside of mandated school activities. The CAPE was found to be reliable and valid.[21] It is translated and validated for the Netherlands.[22] There are three levels of scoring for the CAPE: overall participation scores; scores for two domains (formal and informal activities); and scale scores for five types of activities (recreational, active physical, social, skill-based,

self-improvement). The CAPE provides information on five dimensions of participation: diversity, intensity, experienced pleasure, with whom and where.
Three domains of the CAPE were used for this study, consisting of 55 items, clustered in informal recreation (12 items), physical (13 items) and social activities (10 items). The original CAPE inquires about activities carried out in the past four months. For the purpose of this study, the time frame was adapted to the past week. The completion time is about 20 minutes.

Cognitive/neuropsychological functioning
Cognitive/neuropsychological functioning was measured by means of the Amsterdamse Neuropsychologische Taken (ANT) program.[23] The ANT program evaluates various aspects of cognitive functioning, such as working memory, attention, information processing, executive functioning and visuospatial perception. The ANT was found to be suitable to detect neuropsychological dysfunctions in patients with leukaemia after chemotherapy[24] and psychiatric conditions commonly associated with attention deficit disorders.[25-27]
For this study the following 4 neuropsychological tests from the ANT were administered: Baseline Speed (BS) (test of attention), Feature Identification (FI) (test of memory), Shifting Attentional Set-Visual (SSV) (test of response inhibition and flexibility) and Tracking (TR) (test of visual motor coordination)'.

1. Baseline Speed (BS), a test of attention (alertness) involving minimal cognitive effort. The participant is required to press a mouse-key as quickly as possible when a fixation cross in the centre of the computer screen changes into a white square (n = 32 trials for left and right hand each). Main outcome parameters are the mean reaction time (in milliseconds) of the dominant hand and the within-subject standard deviation of the reaction time (i.e. response speed stability).
2. Feature Identification (FI), a test of memory, measures the ability to discriminate complex visuospatial patterns. This task requires manipulation and monitoring of working memory content. The participant must decide whether a specific visuospatial pattern (a 3x3 matrix of six white and three red squares) is present in a display signal of 4 patterns (n = 80 trials). The difference recognition time (in milliseconds) and accuracy (number of errors) between the similar and dissimilar condition were measured.
3. Shifting Attentional Set - Visual. (SSV), a test of attentional flexibility, an important aspect of executive functioning. A coloured square moves randomly to the right or to the left on a horizontal bar that is permanently present on the computer screen. The task consists of three parts. Depending on the colour of the square, compatible responses (part 1), or incompatible responses (part 2) are required, by pressing the mouse-key on the same side as the direction of movement of the square (part 1), or on the side opposite to the direction of movement of the square (part 2). In these parts, the stimulus-response (SR) compatibility is fixed (either spatially compatible or incompatible). The incompatible condition requires

inhibition of pre-potent responses. During part 3, the colour of the moving square varies randomly, requiring attentional flexibility by continuously having to adjust response type (compatible/incompatible). Discrepancy time (in m sec) and accuracy (number of errors) of the fixed task conditions (averaged across part 1 and 2) and of discrepancy time and accuracy (number of errors), averaged across part 1 and 3, were the outcome parameters.

4. Tracking psychomotor task, which measures quality of movement along a planned trajectory. This task requires the child to trace the mouse cursor in between an outer circle and an inner circle presented on the computer screen (two parts: in clockwise direction with the right hand and in counter-clockwise direction with the left hand). The speed (in sec) and mean deviation (accuracy of movement) were used as outcome parameters.

Achievement of individual treatment goals

With respect to the treatment goals and their achievement, participants were asked to rate their performance regarding a body function or activity related to the treatment goal on a numeric rating scale ranging from 1 "very poor" to 10 "very good" at baseline and after the intervention. A higher score after treatment as compared to the baseline score was considered to be an improvement.

Quality of life

Quality of life was measured with the PedsQL (Paediatric Quality of Life Inventory),[29] consisting of 23 items, divided over subscales: Physical Functioning, Emotional Functioning, Social Functioning, and School Functioning. To compute scale scores, the mean was computed as the sum of the items divided by the number of items within that scale. In addition, to create a Total Scale Score the mean was computed as the sum of all the items over the number of items answered on all the Scales.

The PedsQL has a separate youth and parent version for 4 age groups: 5-7, 8-12, 13-18 and 19-25 years old'. In this study both were used. The reliability and validity are well demonstrated.[26] The time for filling in each version is approximately 5 minutes, with individual differences depending on work speed.

Statistical analysis

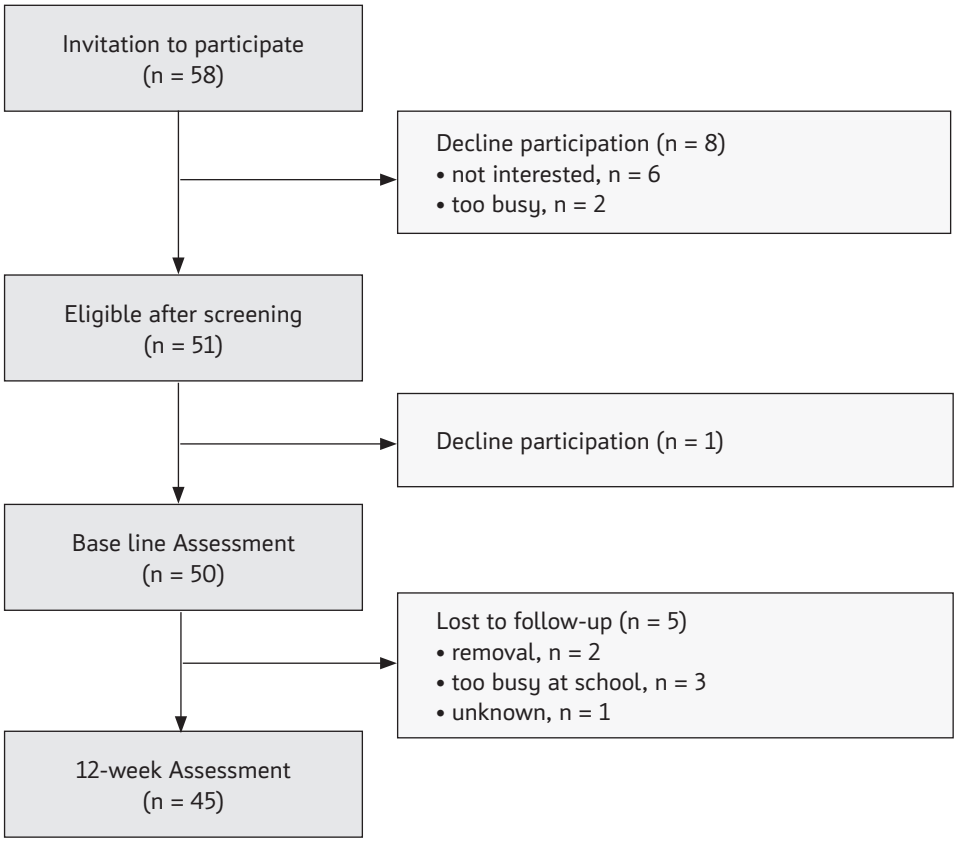
All continuous variables were, according to their distribution, expressed as mean with standard deviation (SD) or median with the interquartile range (IQR). For continuous variables, differences in results at 0 and 12 weeks are presented as the mean change scores from baseline with the 95% confidence interval, and compared using paired t-tests or Wilcoxon signed rank tests, where appropriate. For all analyses, a p-value less than 0.05 was adopted as the criterion for statistical significance. All data were analysed using SPSS version 17.0 software (SPSS, Chicago, IL).

RESULTS

Adherence with the intervention

Forty-five of the 50 included patients (90%) completed the study (see Figure 1). All 50 patients completed the 2 training sessions, but after that 5 were lost to follow up due to lack of time caused by school (3), removal (2) and lack of motivation (1).

Figure 1 Flowchart of patients with acquired brain injury participating in an observational study on the effectiveness of the Nintendo Wii



The baseline characteristics of the included patients and the patients who completed the study are shown in Table 1.

Table 1 Characteristics of 50 patients with acquired brain damage participating in an observational study on the effectiveness of the Nintendo Wii

	All patients n=50	Completers n=45	Non-completers n=5
Age, years			
8-12 (child)	5	4	1
13-18 (adolescent)	30	27	3
19-30 (young adult)	15	14	1
Male sex	31	26	5
Cause of brain damage			
Traumatic	27	22	5
Non-traumatic	23	23	0
Lesion			
Left hemisphere	16	14	2
Right hemisphere	8	6	2
Diffuse	23	22	1
Unknown	3	3	0
Time since diagnosis, years			
0-2 years	9	5	4
> 2 years	39	38	1
Unknown	2	1	1
Current rehabilitation treatment	29	25	4
Current use of assistive device(s)	11	10	1
Main problem[#]			
Gross motor functions	35	33	2
Fine motor functions	27	26	1
Information processing	47	42	5
Language, communication	21	20	1
Solitude, isolation	19	17	2
Self confidence	24	23	1
Physical activity	27	24	3
Experience with gaming (> 3 months)	46	42	4

[#] all patients were asked to list 3 main problems regarding their functioning

Physical, recreational and social activity

Table 2 shows a significant decrease in diversity and an increase in intensity of the reported amount of time spent on physical activity between 0 and 12 weeks. Regarding the CAPE, significant differences over time were seen in diversity of recreational activities and intensity of physical activities. No significant changes were found on the CAPE dimensions related to context (i.e., with whom and where they participate in activities) and enjoyment of activities.

Table 2 Baseline, follow up and change scores of measures of physical, recreational and social activity in patients with acquired brain injury using the Nintendo Wii

	Baseline	Follow-up	Mean Change (95% CI)#	p-value*
	Median (interquartile range)	Median (interquartile range)		
Amount of physical activity	(n=50)	(n=45)		
Physical activity score (1-4)	2.00 (2.00)	3.00 (2.00)	-0.48 (-0.82-0.13)	**.01**
CAPE	(n=43)	(n=43)		
Diversity				
Recreational activities	6.00 (3.00)	5.00 (3.00)	0.60 (0.12-1.08)	**.02**
Social activities	5.74 (3.00)	5.00 (3.00)	0.12 (-0.53-0.76)	.87
Physical activities	3.00 (2.00)	3.00 (3.00)	-0.37 (-0.95-0.20)	.11
Total	14.69 (5.00)	14.08 (5.00)	0.47 (-0.82-1.76)	.49
Intensity				
Recreational activities	2.64 (1.42)	2.48 (1.50)	0.16 (-0.05-0.37)	.14
Social activities	2.90 (1.20)	2.88 (1.80)	-0.02 (-0.31-0.26)	.89
Physical activities	1.32 (1.00)	1.49 (0.77)	-0.19 (-0.40-0.02)	**.04**
Total	2.23 (0.51)	2.17 (0.83)	-0.05 (-0.23-0.13)	.64
Who				
Recreational activities	2.13 (1.17)	2.00 (0.93)	0.12 (-0.10-0.34)	.20
Social activities	2.67 (1.04)	2.75 (1.20)	-0.13 (-0.36-0.11)	.25
Physical activities	2.75 (1.67)	3.00 (1.60)	-0.13 (-0.40-0.13)	.13

CAPE= Children's Assessment of Participation and Enjoyment
#mean change may differ from the difference as computed from the presented median baseline and follow-up values as it concerns the difference obtained by paired comparisons
*p-value of Wilcoxon Signed Rank test

Cognitive/neuropsychological functioning

Table 3 shows the results of the ANT. Due to technical problems we were not able to score the results of five patients. Seven patients failed to complete all four subtests of the ANT, due to a combination of motor problems (n=7), limitations in memory for the instruction (n=3), impulsivity (n=2) or other reasons (n=3). In the patients who completed both ANT tests, there was a significant improvement of the speed of information processing: in reaction time, figure identification, shifting attention, visual motor coordination and in response inhibition. No significant changes were found regarding accuracy.

Achievement of treatment goals

The top-ranked treatment goals and number of patients reporting an improvement are shown in Table 4. Gross motor functioning and Information processing were the two most frequently mentioned goals. At follow-up, two-thirds of the patients reported an improvement, whereas

it appeared that more of them reported an improvement with gross motor function goals than with Information processing goals.

Table 3 Baseline, follow up and change scores of the Amsterdamse Neuropsychologische Taken (ANT) in patients with acquired brain injury using the Nintendo Wii

	Baseline		Follow-up		Mean Change (95% CI)#	p-value*
	n	Median (interquartile range)	n	Median (interquartile range)		
Baseline Speed Reaction time dominant hand	33	303.00 (84.50)	33	287.00 (51.50)	25.27 (4.87-45.68)	**.01**
Baseline Speed Standard deviation	33	74.00 (55.00)	33	63.00 (26.50)	18.97 (-6.60-44.54)	.20
Feature Identification Difference recognition time similar and dissimilar condition	37	867.50 (361.00)	37	675.50 (278.25)	116.64 (32.23-201.05)	**.01**
Feature Identification Number of errors	37	15.00 (15.00)	36	15.00 (16.88)	-0.24 (-5.43-4.95)	.88
Shifting Attentional Set Visual Time difference condition 1 and 2	40	287.00 (302.75)	39	192.00 (283.00)	72.08 (23.25-120.91)	**.005**
Shifting Attentional Set Visual Discrepancy errors condition 1 and 2	40	2.00 (4.00)	39	2.00 (3.00)	-0.19 (-2.29-1.90)	.67
Shifting Attentional Set Visual Discrepancy time of time difference condition 1 en 3	38	422.00 (308.00)	38	381.00 (365.00)	14.97 (-45.94-75.88)	.48
Shifting Attentional Set Visual Discrepancy errors condition 1 en 3	39	3.00 (5.00)	38	3.00 (5.25)	1.24 (-0.77-3.24)	.56
Tracking Speed	40	1.36 (1.36)	38	1.65 (1.11)	0.32 (-0.74-1.38)	**.047**
Tracking Accuracy	40	97.40 (9.52)	38	95.84 (10.69)	-0.44 (-4.69-3.81)	.20

Mean change may differ from the difference as computed from the presented median baseline and follow-up values as it concerns the difference obtained by paired comparisons. *p-value of Wilcoxon Signed Rank test.

Table 4 Treatment goals ranked 1 and their achievement in patients with acquired brain injury (ABI). Results are expressed as numbers of patients

	Treatment goal ranked 1	Improvement at follow-up
Gross motor functions	19	15
Fine motor functions	1	1
Information processing	18	8
Language, communication	3	3
Solitude, isolation	0	0
Self confidence	2	1
Physical activity	1	1
Unknown	1	-
Total	44	29 (66%)

Quality of life

Table 5 shows the results of the PedsQL. Concerning the PedsQL questionnaires completed by the patients, no significant changes over time were seen for any of its domains. For the parent-completed PedsQL questionnaires, a statistically significant improvement was seen in the domain school functioning. Overall, the improvements seen with the parent-completed PedsQL were larger than with the child version.

Table 5 Baseline, follow up and change scores of PedsQL in patients with acquired brain injury using the Nintendo Wii. Values are expressed as median and interquartile range, unless stated otherwise

	Baseline		Follow-up		Mean Change (95% CI)#	p-value*
Patient Administered PedsQL	n	Median (interquartile range)	n	Median (interquartile range)		
Physical Functioning	47	81.25 (25.00)	45	78.13 (23.44)	0.57 (-3.71-4.85)	.71
Emotional Functioning	47	75.00 (25.00)	45	75.00 (20.00)	0.61 (-3.62-4.85)	.63
Social Functioning	47	80.00 (25.00)	45	80.00 (30.00)	3.17 (-1.26-7.60)	.17
School Functioning	46	62.50 (20.00)	45	65.00 (25.00)	-2.02 (-5.95-1.90)	.36
Total Functioning	47	76.09 (20.45)	45	73.91 (18.94)	0.63 (-2.21-3.47)	.66
Parent Administered PedsQL						
Physical Functioning	40	67.19 (37.61)	30	76.56 (36.72)	-3.77 (-12.11-4.56)	.22
Emotional Functioning	40	65.00 (28.75)	30	70.00 (26.25)	-3.26 (-8.13-1.61)	.18
Social Functioning	40	62.50 (30.00)	30	75.00 (37.50)	-3.53 (-11.36-4.31)	.17
School Functioning	39	55.00 (25.00)	29	70.00 (32.50)	-11.39 (-19.3- -3.48)	.009
Total Functioning	40	62.77 (22.42)	30	70.55 (31.79)	-5.10 (-10.98-0.79)	.06

Mean change may differ from the difference as computed from the presented median baseline and follow-up values as it concerns the difference obtained by paired comparisons.
*p-value of Wilcoxon Signed Rank test.

DISCUSSION

In this proof-of-concept observational study it was found that the targeted assignment of Nintendo Wii games increased physical activity, the speed of information processing, attention, response inhibition, and parent-perceived Quality of life (QoL) in children and youth with ABI. In addition, the majority of participants indicated an improvement of their major treatment goal. No changes were seen regarding the context of activities as measured with the CAPE, accuracy and patient-perceived quality of life.

In general the results of the present study are in line with those of other studies employing the Wii in patients with ABI,[17-20] all demonstrating positive effects on motor functioning. In contrast with the previous studies, our study included outcome measures regarding overall physical activity, neuropsychological functioning, societal participation and quality of life. In our study we failed to demonstrate an effect of the intervention on societal participation (diversity, i.e. with whom and where) and enjoyment of activities as measured with the CAPE. So far, the CAPE has only sparsely been employed in longitudinal studies in patients with cerebral palsy. In these cases it was not used with the aim to detect changes over time. In research with patients with ABI the CAPE was not used before. Additional research is needed to examine the validity and responsiveness of this measure in this patient group.

In addition, with the exception of school functioning (scored by parents), no changes of quality of life, as measured with the PedsQl were seen. It remains to be established to what extent gaming has an impact on QoL and to what extent the PedsQl is able to detect clinical changes in patients with ABI. In addition, whereas some of the previous studies included measures of posture and balance[19,20] at all our study did not specifically aim to examine the effect of the Wii on these measures. As problems with balance are likely to be common in the patient group with ABI, future research should include a measure of balance.

The variety of dimensions of health status and outcome measures used in the available studies underlines the need for consensus on a core set of outcome to be used in studies on virtual reality and interactive video gaming in patients with ABI . Such a core set would have to cover all elements of health status, including body structures and functions, activities, societal participation, and personal and environmental factors, supported by imaging techniques such as functional Magnetic Resonance Imaging (fMRI). With the choice of outcome measures, the age range of the patient group must be taken into account, as many instruments have only been validated in patients of specific age groups.

Another issue that needs attention is an adequate description of the intervention with the Nintendo Wii. In some of the aforementioned studies with the Nintendo Wii a limited number of games was employed. In our study, despite using a fixed protocol, the potential range of games that could be matched to specific treatment aims was relatively large, so that a standardized description of the intervention is difficult to make. If however the choice had

been more limited, the preselected games may not have matched the patients' individual preferences and situation, which could have had a negative impact on adherence with the intervention. Currently, initiatives are being taken to develop a standardized classification of VR and gaming, to support clinical decision making as well as research.[14]

Regarding compliance, all participants took part in both training sessions. We did not register the actual time spent on gaming, as adherence with filling out detailed diaries in this did not appear feasible in this patient group. Therefore, in future research, adding a 'timer' to the game, to record the length of time spent gaming) is needed. This is in part reflected by the response to the questionnaires, which ranged between 90 and 99% at both time points. In addition, the proportion of patients who completed the ANT was also limited, a software problem caused loss of data of 5 participants during data analysis. These observations stress the need to carefully select outcome measures that are feasible in this patient group and the inclusion of sufficient numbers of patients, as attrition rates can be substantial.

This study has a number of limitations. Its most important weakness is the absence of a comparison group, so that no firm conclusions about the effectiveness of the intervention can be drawn. In addition, the employment of a large set of outcome measures may have enhanced the chance of finding statistically significant differences. However, the favourable findings warrant the need for larger clinical trial, comparing the effectiveness of an intervention with the Nintendo Wii with other interventions that proved to be beneficial in patients with ABI.

CONCLUSIONS

This study substantiates the potential benefits of gaming in patients with ABI. A larger, controlled study is required to prove the effect of gaming on motor, communicative, neurocognitive and social emotional functions and activities in this patient group.

Acknowledgment

We are indebted to the participants and their parents, and to the therapists and teachers who delivered the intervention and performed the assessments.

Declaration of Interest statement

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