



Received: 07 October 2015
Accepted: 12 January 2016
Published: 24 February 2016

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CLINICAL PSYCHOLOGY & NEUROPSYCHOLOGY | RESEARCH ARTICLE

Cognitive rehabilitation of attention deficits in traumatic brain injury using action video games: A controlled trial

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Abstract: This paper investigates the utility and efficacy of a novel eight-week cognitive rehabilitation programme developed to remediate attention deficits in adults who have sustained a traumatic brain injury (TBI), incorporating the use of both action video game playing and a compensatory skills programme. Thirty-one male TBI patients, aged 18–65 years, were recruited from 2 Australian brain injury units and allocated to either a treatment or waitlist (treatment as usual) control group. Results showed improvements in the treatment group, but not the waitlist control group, for performance on the immediate trained task (i.e. the video game) and in non-trained measures of attention and quality of life. Neither group showed changes to executive behaviours or self-efficacy. The strengths and limitations of the study are discussed, as are the potential applications and future implications of the research.

Subjects: Allied Health; Neurological Rehabilitation; Neuropsychological; Rehabilitation; Rehabilitation Medicine

Keywords: cognitive rehabilitation; action video game; traumatic brain injury; attention

1. Introduction

Traumatic brain injury (TBI) often results in cognitive impairments that cause significant ongoing impediments to work, study, daily living and social relationships. An examination of clinically significant cognitive impairments following TBI, found a high frequency of impairments in attention, memory and executive functioning at time of admission, and at 18 months, 3 years and 5 years post trauma. Yet no consensus has been reached on the most effective way to rehabilitate cognitive deficits in TBI.

ABOUT THE AUTHOR

This research was conducted as part of a PhD at Macquarie University, Sydney, Australia. The author is currently a paediatric neuropsychologist working with children and adolescents. The author is currently building cognitive rehabilitation programmes for use with Psychiatric inpatients with a particular focus on executive functioning.

PUBLIC INTEREST STATEMENT

The rehabilitation of cognitive deficits following traumatic brain injuries (TBI) is paramount to bettering the functioning of patients who have sustained such injuries. In addition, to the wider community reducing the level of disability of people who have sustained TBI's has large economic benefits.

However, to implement cognitive rehabilitation programmes successfully we need adequate empirical investigations and ecologically valid outcome measures. We also need to address the economic limitations of public health care systems and utilise technology to overcome some historical limitations in this approach.

Historically, remediation of attention deficits in TBI has utilised a restorative drill and practice approach with visual or auditory stimulus–response paradigms. Cicerone et al. (2000, 2005, 2011) reviewed the literature on cognitive rehabilitation for attention deficits following TBI and concluded that while attention training benefits patients beyond the specifically trained task, the effects may be small and/or remain relatively task-specific. These researchers also identified the need to examine the impact of attention training on other cognitive functions, such as executive functions, and activities of real-world daily living.

Few well-controlled studies have examined the effects of cognitive rehabilitation on executive deficits in TBI, with most research to date focusing on individualising treatments to a particular patient’s needs. In his methodological reviews, Cicerone et al. (2000, 2005, 2011) concluded that the most effective methods to improve everyday problems caused by executive deficits in TBI patients promoted internalisation of self-regulating strategies, for example, using verbal self-instruction, self-questioning and self-monitoring. While research has found only limited evidence for the effectiveness of group-based executive functioning training in TBI, goal management training has been reported to produce modest improvements in daily activities Rees, Marshall, Hartridge, Mackie, & Weiser, (2007).

Against this background, this paper reports a novel cognitive rehabilitation programme for attention deficits in TBI using the economically viable approach of action video games and incorporating a psycho-educational approach.

1.1. Rationale for using action video games

The exponential increase in sophisticated technology over the past 20 years has opened up many new possibilities for relatively inexpensive computer-assisted cognitive rehabilitation approaches. A systematic review of these approaches found significant improvements in performance on related laboratory tests, such as standardised neuropsychological assessments of cognitive functioning, but the durability and generalisability of findings have yet to be adequately assessed (Chesnut et al., 1999). Given that the typical demographic of TBI survivors is young males, a computer-assisted intervention that appeals to this demographic may enhance the benefits of such programmes. One such approach utilises commonly available “video gaming”, cutting down demands for specialised equipment and face-to-face therapist contact.

Of particular relevance to the present study, playing action video games has been shown to improve visual attention. Green and Bavelier (2003) reported in their influential *Nature* paper that 10 days of training on an action video game increased basic attentional skills. Their first experiment showed that video game players possess enough attentional capacity to attend to both target and distracter stimuli, whereas the attentional resources of non-video game players had depleted by the most difficult trial. In a second experiment, these authors showed that video game players were also able to process more items at once compared with non-players, supporting a higher capacity of the visual attentional system of the video game players. In a third experiment, the video game players outperformed the non-players in localising a target amongst a spatial array of distracters, indicating an increased spatial attention capacity. Their fourth experiment examined temporal characteristics of visual attention using an experimental, identification/detection “attentional blink” task and found that video game players had better temporal processing of visual information and enhanced task-switching ability.

Their fifth and final experiment aimed to establish that the group differences were due to the effects of video game training as opposed to any pre-existing differences and selection bias towards playing or not playing games. Non-players were trained on the action video game, “Medal of Honor”, for 1 hour a day for 10 days. Training resulted in improvements on all aforementioned tasks. However, while other researchers have replicated the results of experiments one to four from Green and Bavelier (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Dye & Bavelier, 2010), Boot et al. (2008) failed to replicate the fifth experiment. Nevertheless, other related research has found that action

video game players make faster and more accurate judgments on the Attentional Network Test, a test examining one's alerting, orienting and executive attention, when compared to non-players (Dye, Green, & Bavelier, 2009) and that training on video game playing improves strategies of divided attention (Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994).

In the light of the above findings, the current study utilises an action video game and a commercially available video game console (i.e. the Sony PlayStation) as a cognitive rehabilitation tool for TBI.

1.2. Rationale for incorporating a psycho-educational approach

There is some debate in the literature as to the best way to accomplish generalisation of learning. Some suggest that to enable functional change, skills should only be taught in the specific situation in which they will be utilised (e.g. teaching job skills in the work environment: Guercio & Fralish, 1998), while others believe that by teaching more general principles, learning can be transferred to a wider range of scenarios, enabling generalisation (Schutz & Trainor, 2007). Of relevance to the present study, the attention process training (APT) programme aims to retrain attention by providing various tasks of increasing difficulty (Sohlberg & Mateer, 1987) with additional tasks incorporated to promote generalisation. These researchers have since assessed the effectiveness of combining APT with compensatory techniques (e.g. brain injury education and support) (Moore Sohlberg, McLaughlin, Pavese, Heidrich, & Posner, 2000) and found improvement on various neuropsychological measures of attention and executive functioning, and self-reported changes in attention and memory functioning, thus suggesting generalisation of treatment effects.

In the current study, we provide compensatory strategies as part of a comprehensive adjunct psycho-educational programme to enhance the generalisation of attention training via action video-gaming to TBI patients' everyday lives.

1.3. Study hypotheses

We hypothesise that the action video-gaming and psycho-education programme will result in improvements in attentional blink task performance and other, more ecologically valid attention measures such as The Test of Everyday Attention. Additionally, we hypothesise that there will be generalisation of improved skills to real-world executive behaviours which will thereby translate into improved self-efficacy and quality of life.

2. Methods

2.1. Participants

Thirty-one participants were recruited from two brain injury rehabilitation units in Sydney, Australia. Five participants dropped out before completion, leaving 26 participants at the time of the final analysis. All participants were male, between 18 and 65 years old, and had sustained a TBI at least one year prior to the first assessment.

2.2. Measures

2.2.1. Participant demographics

The following demographic information was taken: age at injury (in years), age at first assessment (in years), time since injury (in months), days of post-traumatic amnesia (PTA) and years of education.

2.2.2. Game performance

Two measures indexed game performance: number of "deaths" before level completion and shooting accuracy. Specifically, at the initial or second training session, participants recorded the number of times their character died before completing mission three. Their shooting accuracy percentage,

as provided by the game, was recorded at the end of the initial session. At the last training session, participants were asked to return to mission three and the number of deaths and shooting accuracy were again recorded.

2.2.3. Attentional blink task

Stimuli were generated by a Toshiba laptop computer and displayed on a 13-inch (32.5 cm) colour monitor. Subjects viewed the display binocularly from a distance of approximately 35 cm. Each trial comprised of a fixation cross presented for 500 ms followed by a sequence of black, uppercase distracter letters and a single white target letter. Half of the trials also included a black “X”. Each stimulus in the sequence appeared at the same location in the centre of a uniformly grey screen for 15 ms, with an interstimulus interval of 75 ms. In half of the trials with an “X”, the “X” appeared at one of eight time lags following the white letter. Participants were instructed to look for the white letter and a black “X” and responded by identifying the white letter and indicating if an X was present or absent. After 15 practice trials, there were 4 blocks of 40 test trials each. In each block, five initial warm-up trials were not included in the analysis. In accord with previous research, the dependent variable (DV) was percentage correct detection of the X, given correct letter identification, at each of the eight lags.

2.2.4. The test of everyday attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1996)

The subtests and domains of everyday attention are outlined in Table 1. Version A was used for the initial assessment and version B for post-treatment assessment. The DVs are age-normed scores and take account of the practice effects that typically occur at the second administration (range 0–20). Reliability statistics for the Test of Everyday Attention range from .57 to .87. Convergent validity has been shown with other attention measures (Stroop, Trails A and B and Matching familiar figures test) and divergent validity has been shown with intelligence and academic attainment tests.

2.2.5. Quality of life

The Comprehensive Quality of Life Scale Fifth Edition—for Intellectual/Cognitive Disability (ComQoL-I5) (Cummins, McCabe, Romeo, Reid, & Waters, 1997) measures subjective quality of life across seven domains: Material well-being; Health; Productivity; Intimacy; Safety; Place in Community; and Emotional well-being. As per the manual, scores indicating level of satisfaction

Table 1. Subtests of the test of everyday attention and the cognitive factors they examine

Subtest (s)	Description of tasks	Cognitive factor
Map search	Searching a visual array and selecting targets whilst ignoring distracters. Task is timed	Visual selective attention/speed
Telephone search	Searching a visual array and selecting targets whilst ignoring distracters. Task is timed	Visual selective attention/speed
Visual elevator (number correct)	Switching between counting forward and backward according to visual stimuli that demand multiple occasions of switching	Attentional switching
Elevator counting	Sustaining attention to two repetitive auditory stimuli at the same time	Sustained attention
Telephone search (dual task decrement)	Sustaining attention to two stimuli at the same time (one auditory and one visual)	Sustained attention
Elevator counting with distraction	Counting auditory stimuli while ignoring distracting stimuli	Auditory-verbal working memory
Elevator counting with reversal	Switching between counting forward and backward according to auditory stimuli	Auditory-verbal working memory

(rated on a five-point scale ranging from “very sad” to “very happy”) were weighted by subjective importance (five-point scale ranging from “not important at all” through to “could not be more important”) to calculate a subjective quality of life score for each domain (range –20 to 20). Reliability statistics for the ComQol-I5 range from .0–.97. No data on validity have been provided (Table 2).

2.2.6. Self-efficacy

The General Self-Efficacy Scale (GSES: REF) is a 10-item self-report questionnaire that uses 5-point Likert scales (1–4) to examine optimistic self-beliefs about coping with life’s demands (range 10–40). The GSES has reliability statistics ranging from .76 to .90. Convergent and divergent validity have been shown.

2.2.7. Executive functioning

The Behavior Rating Inventory of Executive Functioning-Adult version (BRIEF-A) is a 75-item self-report questionnaire. The participant is instructed to report during the past month how often each of a number of executive behaviours have been a problem: “never”, “sometimes” or “often”. Responses are summed into nine factors: inhibit, shift, emotional control, self-monitor, initiate, working memory, plan/organise, task monitor and organisation of materials. These scales are combined to form two indexes, The Behavioural Regulation Index (BRI) and Metacognition Index, and an overall summary score, The Global Executive Composite. All scores were converted to T scores as per the manual (range 35–88). Reliability statistics are adequate to good (internal consistency .80–.98;

Table 2. The eight-week psychoeducational programme

Week	Module	Topics
1	Introduction and psycho education	Having a positive approach to rehabilitation Short and long term effects of TBI How to play Medal of Honor
2	Attention	What is attention? What impacts my ability to pay attention? Self-monitoring Pacing strategies
3	Memory	What are the different phases of memory? Where do I have the most difficulty? Encoding strategies Storage strategies Retrieval strategies
4	Anger Management	Becoming motivated Recognising anger before onset Strategies for coping with anger
5	Problem-Solving	The goal-plan-predict-do-review framework
6	Fatigue and Lack of Motivation	What is fatigue and what causes it? Using task analysis
7	Goal Setting	Identifying goals Planning goal execution Executing goal-directed behaviours
8	Programme review and building confidence	Mantras Being assertive

inter-rater reliability .30–.50; test retest reliability .76–.85). Correlation studies have shown good convergent and divergent validity.

2.3. Procedure

2.3.1. Pre and post-treatment assessment

Potential participants were alternately assigned into either an attention training or treatment as usual (TAU) group. The Test of Everyday Attention was administered first, following the manual. The questionnaires were then administered with instructions simplified if necessary and questions read aloud for those participants with reading difficulty. The attentional blink task was always administered last. Administration took between one and two hours. Post-treatment assessment occurred between one and three weeks after the programme.

2.3.2. Attention-training

Participants attended a two-hour group rehabilitation session once a week for eight weeks. Groups consisted of four to five participants, each with his own PlayStation 2, 19-inch flat screen, game, memory card and rehabilitation programme. In each session, participants played “Medal of Honor: Rising Sun” (MoHRS; Electronic Arts, 2003), a first-person shooter action video game, set in Second World War, for approximately three-quarters of the session. The remainder of the time was dedicated to a psycho-education programme addressing common consequences of brain injury and introducing compensatory strategies.

2.3. Statistical analysis

Baseline comparisons between groups for all measures were completed using one way Analysis of Variance (ANOVA). Mixed model ANOVAs analysed the interaction of Time by Group (i.e. examining pre-post changes in the attention-training group relative to any changes over time in the TAU group) for all outcome DVs. Spearman correlations examined relations between improvement in game scores (Shooting Accuracy and Number of Deaths) and improved outcome measures for the treatment group.

3. Results

3.1. Participant attrition

As per Figure 1, all 15 attention-training participants completed the training and post-treatment assessment. Of the initial 16 TAU participants, five dropped out prior to the second assessment, leaving 11 in the post-treatment assessment comparison group. Of these 11, only 5 went on to complete attention-training, which was offered to all TAU participants.

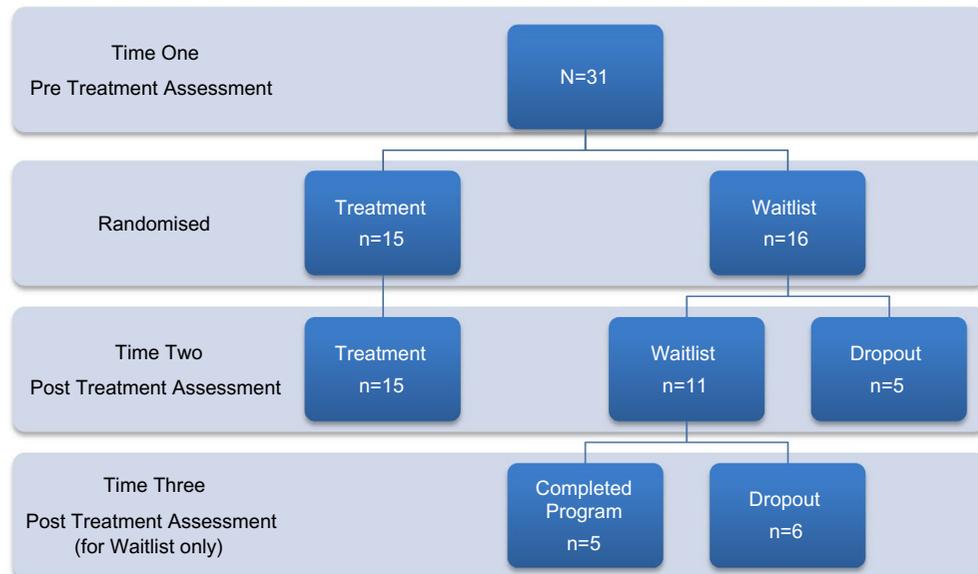
3.2. Baseline group comparison

Baseline data were examined in three ways: (1) all 31 participants (the intent-to-treat groups of 16 TAU and 15 attention-training participants); (2) the 26 participants who completed post-treatment assessment (the per protocol groups of 11 TAU and 15 attention-training participants); and (3) the 5 participants who dropped out before the post-treatment assessment compared to the 26 who completed the protocol.

3.2.1. Participant demographics

Refer to Table 3 for a summary of the data. Analysis of all 31 participants showed that the attention-training and TAU groups did not differ at baseline on current age, age at time of injury, years of education or length of PTA; all p -values $> .05$. Time since injury was significantly different ($F(1,30) = 4.746$, $p < .05$), with the attention-training group having a longer time since injury compared to the TAU group. However, analysis of the 26 participants who completed the study found no differences on any demographics; all p -values $> .05$. The five participants who dropped out were also no different from the rest on any demographic; all p -values $> .05$.

Figure 1. Participant attrition.



3.2.2. Treatment outcome measures

Analysis of all 31 participants showed no significant differences between groups on the baseline attentional blink measures, Test of Everyday Attention, executive functioning (BRIEF-A) or quality of life (ComQol-I5); all p -values $> .05$. Baseline self-efficacy (GSES) was, however, significantly higher in the TAU group ($F = 4.68, p < .05$). However, analysis of the 26 participants who completed the study showed no differences between groups on any outcome measures; all p -values $> .05$. The five participants who dropped out had higher baseline ratings of emotional well-being (ComQol-I5 satisfaction with emotional wellbeing ($p < .005$) and weighted importance \times satisfaction score; ($p < .05$) but were found to be no different from the participants who completed the programme on other Quality of Life factors and all other measures; all p -values $> .05$.

3.3. Pre- to post-treatment analyses

3.3.1. Game performance

As shown in Table 4, at the final session attention-training participants had significantly improved in their shooting accuracy ($t = -4.896, p < .0005$) and the number of deaths it took to complete a level ($t = 8.271, p < .0005$).

Table 3. Participant demographics

	Attention-training group $n = 15$	Initial TAU cohort $n = 16$	Final TAU cohort $n = 11$	Drop-outs by time two = 5
Age (at first assessment)	27.73 (11.43)	28.63 (6.54)	29.36 (6.34)	27.00 (7.42)
Age (at time of injury)	24.67 (10.91)	26.63 (6.88)	27.00 (7.09)	25.80 (7.12)
Months since injury	38.93 (30.05)	21.81 (9.02)	22.18 (10.50)	21.00 (5.34)
PTA (Days)	41.87 (43.87)	43.64 (35.64)	37.30 (32.02)	50.50 (44.26)
Education (Years)	11.33 (1.91)	10.37 (1.09)	10.45 (1.29)	10.20 (.45)

Table 4. Changes in game performance in the attention-training group following 8 weeks of training

		Mean	Std. Dev.	t	p
Accuracy	Pre	17.35%	.113	-4.896	<.0005
	Post	30.00%	.180		
Deaths	Pre	11.38	6.76	8.271	<.0005
	Post	1.85	2.27		

3.3.2. Attentional blink

Twenty-three participants completed the attentional blink task at both assessments. Three participants were not included because they either refused to participate ($n = 1$) or discontinued the task prematurely ($n = 2$).

The mixed model ANOVA used a $2 \times 2 \times 8$ (Pre-post by Group by Lag) design. Results showed a significant main effect of lag ($F(7,15) = 10.463, p < .0005$), such that detection of the black X, given correct report of the letter, improved as the lag between the letter and the X increased. Neither the main effect of Pre-post, ($F(1,21) = 3.897, p = .062$), nor the interaction of Pre-post by Group were statistically significant ($F(1,21) = 1.90, p = .183$). Although the two-way interaction was not significant, the pattern of data is suggestive of differential effects across groups. Given the relatively small sample size and the possible limitations of power, further exploratory analyses were performed by splitting the groups. In the separate 2×8 (Pre-post by Lag) analyses, the TAU group showed a significant main effect of Lag ($F(7,4) = 6.061, p < .0005$) and a non-significant effect of pre-post ($F(1,10) = .129, p = .727$). In contrast, the attention-training group showed significant main effects of Lag ($F(7,5) = 4.577, p < .0005$) and Pre-post ($F(1,11) = 8.315, p < .05$), such that performance, irrespective of Lag, was superior after attention-training.

3.3.3. Test of everyday attention

Results were analysed using a 2×2 (Pre-post by Group) analysis (see Table 5). Significant two-way interactions were found for Map Search (2 min), Elevator Counting with Distraction and Visual

Table 5. 2×2 mixed model ANOVA interactions for the test of everyday attention

		Mean		F interaction (1,24)	p
		Attention-training	TAU		
Map 1 minute	Pre	5.07	4.45	.879	.358
	Post	6.93	5.00		
Map 2 minute	Pre	3.20	3.00	7.442	.012
	Post	5.67	1.64		
Elevator with distraction	Pre	7.20	9.09	8.688	.007
	Post	8.67	6.91		
Visual elevator accuracy	Pre	9.00	9.45	.044	.836
	Post	7.80	8.55		
Visual elevator time	Pre	4.64	4.91	10.394	.004
	Post	6.21	1.55		
Elevator counting with reversal	Pre	7.07	8.55	2.552	.123
	Post	7.40	7.18		
Telephone search	Pre	7.40	4.55	1.97	.173
	Post	8.27	2.73		
Dual task	Pre	7.00	6.00	2.085	.162
	Post	7.20	3.73		

Elevator Time. All other main effects and interactions were not statistically significant. The interaction for Map Search (2 min) occurred because the attention-training group showed a significant improvement from pre- to post-treatment assessment ($t(14) = -2.193, p = .046$), while the TAU group showed a significant decrement in their performance ($t(10) = 2.443, p = .035$). The same general pattern was seen for Elevator with distraction and Visual Elevator Time. With regard to Elevator with distraction, the Pre-post difference for the attention-training group showed a trend toward improvement ($t(14) = -1.785, p = .096$), while the TAU group showed a significant decrement ($t(10) = 2.39, p = .038$). With regard to Visual Elevator Time, the improvement for the attention-training group was non-significant ($t(13) = -1.465, p = .167$), while the TAU group showed a significant decrement ($t(10) = 3.187, p = .010$).

3.3.4. Executive functioning (BRIEF-A)

No effects reached statistical significance (see Table 6 for a summary of the data); all p -values > .05.

3.3.5. Self efficacy (GSES)

All results (see Table 6) were non-significant; all p -values > .05.

Table 6. Results of 2 × 2 mixed model ANOVAs for the behavioural rating inventory of executive functioning-adult version (BRIEF-A) scales and the general self-efficacy scale (GSES)

		Mean		F interaction (1,24)	p
		Attention-training	TAU		
<i>BRIEF-A</i>					
Inhibit	Pre	60.04	59.27	.266	.611
	Post	59.2	56.09		
Shift	Pre	62.47	59.72	.543	.468
	Post	61.4	54.09		
Emotion	Pre	61.73	59.91	.097	.758
	Post	56.27	56.36		
Self monitor	Pre	60.4	54	.211	.65
	Post	58.4	54.273		
Behavioural regulation index	Pre	64	60.55	.001	.97
	Post	60.4	56.72		
Initiate	Pre	56.47	54.72	.033	.857
	Post	54.73	52.18		
Working memory	Pre	62.53	59.72	.091	.765
	Post	63.6	59.09		
Plan/organise	Pre	60.13	52.91	.167	.687
	Post	58.6	53.36		
Task monitor	Pre	57.6	53	0	.989
	Post	57	52.46		
Organisation of materials	Pre	49.6	51.09	.388	.539
	Post	52.47	50.82		
Metacognitive index	Pre	58.33	54.73	.221	.642
	Post	61.4	55.55		
General executive index	Pre	61.67	57.73	.015	.902
	Post	59.87	55.46		
<i>GSES</i>					
	Pre	27.38	31.30	1.129	.297
	Post	29.00	31.20		

3.3.6. Quality of life (ComQol-I5)

See Table 7 for a summary of results for the weighted satisfaction by importance scores for the seven scales. The Pre-post by Group interaction was significant for material well-being and emotional well-being. All other interactions were non-significant; and no main effects were significant (all p -values $> .05$). Simple comparisons revealed that the attention-training group self-reported significantly higher scores for material well-being after training compared to baseline ($t(15) = -2.616$, $p = .02$), while scores for the TAU group dropped, although not significantly ($t(11) = 1.605$, $p = .14$). The pattern for Emotional well-being was generally similar; the scores for the attention-training group showed improvement after treatment, although non-significant ($t(15) = -1.378$, $p = .19$), while the TAU group showed a trend toward lower scores ($t(11) = 2.149$, $p = .057$).

3.3.7. Game Improvement and Outcome Improvement

Spearman correlations revealed that improvements in fewer “deaths” correlated with improvements in elevator counting with distraction ($r = .365$, $p < .043$), while all other correlations were non-significant ($p > .05$).

4. Discussion

This study aimed to investigate the effect of an eight-week cognitive rehabilitation programme for TBI incorporating action video gaming and psycho-education. Participants in the attention-training condition showed significant improvements in game performance (shooting accuracy and the number of deaths it took to complete a level). This finding shows the direct benefit of the video game experience on the video game playing itself and is consistent with previous research. Additionally, it extends the existing research into the effects of action video game experience to also include a TBI population. However, it is the generalisation of these skills to other tasks and measures that is of paramount importance.

Results for the experimental attentional blink task showed an effect of lag in both groups, indicating greater attentional blindness at shorter time lags. Separate analyses indicated that whereas the TAU group did not change from pre- to post-treatment, the attention-training group demonstrated a significant improvement in detection of the second target across all time lags. This finding is consistent with the findings of Green and Bavelier (2003), who observed a similar reduction in attentional blink across all lags following 10 h of video game training in healthy participants.

Table 7. 2 × 2 mixed model ANOVA for the comprehensive quality of life scale

QoL		Mean		F interaction (1,24)	p
		Attention-training	TAU		
Material	Pre	1.133	5	8.515	.008
	Post	9.2	-1.318		
Health	Pre	6.63	3.27	.192	.665
	Post	8.93	3.41		
Productivity	Pre	8.9	11.5	1.784	.194
	Post	12.7	11.86		
Intimacy	Pre	15.4	11.82	.002	.964
	Post	12.27	8.91		
Safety	Pre	7.73	7	.227	.638
	Post	10.33	7.86		
Community	Pre	5.93	4.05	1.223	.28
	Post	9.93	3.09		
Emotional	Pre	6.27	7.45	6.095	.021
	Post	10.23	.91		

Only three tasks on the Test of Everyday Attention (TEA) revealed different profiles of pre- to post-treatment assessment across groups; Map Search (2 min), Elevator Counting with Distraction and Visual Elevator (Time). Comparisons indicated that the attention-training group showed a significant improvement on Map Search (2 min) with similar, albeit not significant, improvements on the other two TEA measures. In contrast, the TAU group showed significant declines. On the TEA, two versions of the test are administered and normative scores for the second administration account for practice effects. The important implication here is that the reduction in scaled scores suggests that the TAU group did not benefit from practice as would be expected or their performance deteriorated. In contrast, the attention-training group was able to benefit from practice and, moreover, improved, albeit only significantly for Map Search (2 min). One final comment is the fact that Map Search and Visual Elevator are timed. Hence, consistent with some reviews (Rees et al., 2007), it may be that our results reflect changes in processing speed rather than attention per se.

There were no benefits of training seen on any scales from the BRIEF-A (executive functioning) or on the GSES (self-efficacy). This null finding is consistent with a review by Rees et al. (2007), who found limited evidence for the effectiveness of group training on executive functioning. However, it is also possible that our self-report measurements were confounded by poor insight in TBI. Results for quality of life were more promising. The interactions between time of assessment and group were significant for material well-being and emotional well-being. Analysis of the pre- and post-treatment scores indicated that the attention-training group had significantly higher ratings of material well-being after treatment, while the control group showed no such change. It must be acknowledged, however, that the attention-training participants were compensated \$20 per session for their participation; thus, their perceived material well-being may have been directly impacted by this compensation, rather than being related to any work or job related gains. This explanation is less likely to account for the interaction effect for emotional well-being: the control group showed a significant drop in emotional well-being, while the treatment group showed some benefit from training, at least to some degree.

Before final conclusions, limitations of the study are acknowledged. Firstly, our programme incorporated both restorative and compensatory techniques. Each of these components has been shown to impact different skills, with more evidence for the effectiveness of restorative techniques in the rehabilitation of attention, and greater evidence of the effectiveness of compensatory techniques in increasing the generalisation of skills learnt to everyday functioning. By incorporating both into one programme, it is not possible to tease apart the independent effects of these two techniques. Nevertheless, the finding that improvement in game performance correlated with at least one attentional outcome measure suggests that there was a direct restorative contribution from the gaming experience itself. Secondly, our control group did not receive any therapeutic intervention. Therefore, may be the case that benefits were due to participating in ANY group, regardless of the activity being undertaken. As noted above, though, the finding that improvement in actual game performance correlated with at least one attentional outcome measure suggests that not all benefits were due to general group participation. Future research should nevertheless aim to include an active control group. Finally, as with much of the cognitive rehabilitation research our sample size was small, resulting in limitations of power.

This study also had strengths, however. First and foremost, we report the development and testing of an economically viable option for a health care system that has limited resources. The materials used (a Sony PlayStation and TV) are readily available and inexpensive. The game we used is commercially available, and the programme can be adapted for any commercially available action video game. In fact, video game consoles are often already available in Brain Injury Rehabilitation Units and certainly in people's homes. Second, the group nature of the programme means that the therapist can treat multiple participants at one time. Not only is this an efficient use of the therapist's time, but it also enables therapeutic benefits of social interaction and group participation. Other strengths include that this study utilised a number of measures that are more ecologically valid than some more widely used alternatives. The Test of Everyday Attention uses everyday tasks

such as searching through maps or telephone books and assesses the same set of different domains that match the factor structure known to represent attention functioning (Robertson et al., 1996). We also used behavioural questionnaires to gauge behavioural changes in executive functioning, rather than an intermediate cognitive measure. A measure of quality of life was also included to assess the broader impact of the training on multiple aspects of daily functioning. We do acknowledge, however, that data from self-report questionnaires may be confounded by poor insight in TBI.

In conclusion, the current study has shown that comprehensive cognitive rehabilitation programmes that address both restorative and compensatory techniques, have the potential to benefit individuals with TBI. Given the limitations of the study, the findings provide a rationale for more rigorous cognitive rehabilitation research with larger sample sizes. Importantly, the current programme was designed to enable access to cognitive rehabilitation in an economically viable way. Given the availability of video games in the homes of many TBI patients and the likelihood that they may spend a portion of their day playing video games, the programme could potentially be adapted for home use with an administration manual to assist a family member or caregiver in supervising the TBI patient and to enable adequate explanation through the process.

Funding

The authors received no direct funding for this research.

Competing Interests

The authors declare no competing interest.

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Citation information

Cite this article as: Cognitive rehabilitation of attention deficits in traumatic brain injury using action video games: A controlled trial, Alexandra Vakili & Robyn Langdon, *Cogent Psychology* (2016), 3: 1143732.

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