Running head: Virtual reality and psycho-emotional health

What is the impact of engaging with natural environments delivered via virtual reality on the psycho-emotional health of people with spinal cord injury receiving rehabilitation in hospital? Findings from a pilot randomized controlled trial

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What is the impact of engaging with natural environments delivered via virtual reality on the psycho-emotional health of people with spinal cord injury receiving rehabilitation in hospital? Findings from a pilot randomized controlled trial

Objectives: This study investigated (i) the impact of engaging with 20 minute simulated natural environments delivered via virtual reality (VR) on current mood state, and (ii) the impact of engaging with multiple VR sessions over a period of a week on the depressive symptoms of people with a SCI.

Design: A randomized controlled trial design was utilised.

Setting: Spinal Cord Injury Rehabilitation Unit in Australia

Participants: Participants (n=24) were assigned to a group engaging in VR sessions during week 1 (Group 1, n=10), or week 2 (Group 2, n=14).

Interventions: The intervention week involved participation in up to three 20-minute VR sessions over three consecutive days. The control condition involved regular rehabilitation practice over a week.

Main Outcome Measures: The Patient Health Questionnaire-8 (PHQ-8) was completed prior to the first week (T1), after the first week and prior to the second week (T2), and after the second week (T3). Current feeling states- depressed/happy, anxious/relaxed, and not feeling good/feeling good - were rated immediately prior and after each VR session.

Results: Levels of happiness, relaxation, and feeling good, were significantly higher subsequent to engaging with each VR session. Between-group differences in PHQ-8 scores were significantly greater for participants who experienced the intervention during the first week compared to participants within the control group: intervention participants had significant improvements in psycho-emotional health. Within-group PHQ-8 scores reduced

for each group subsequent to experiencing the intervention, however differences were not significant.

Conclusions: Engaging with simulated natural environments delivered via VR can favourably impact the psycho-emotional health of people with SCI receiving rehabilitation in hospital. Future research including larger samples and investigating the impact over a longer time period is required to confirm the findings presented.

Keywords: inpatient rehabilitation; spinal cord injury, psycho-emotional health, virtual reality, natural environments

Abbreviations: Spinal Cord Injury (SCI), Virtual Reality (VR)

Spinal cord injury (SCI) is a condition that has a considerable impact on individuals who experience injury and health and social care systems. Globally, it is estimated that between 250,000 and 500,000 people experience an SCI yearly.[1] In Australia, the lifetime cost of health and social care for each SCI is between 5 and 10 million dollars, and this number is set to increase with an ageing population.[2] While in relation to acute care, the cost of initial hospitalisation for each injury is between 23 and 32 thousand dollars.[3] In part, the considerable costs are due to the diverse physical and psychosocial consequences of experiencing an SCI.

Experiencing an SCI can result in adverse psycho-emotional health consequences, [4,5] including increased levels of anxiety [6] and depression. [7-9] These health outcomes are apparent from the acute stage of injury up until transition to the community.[4] The issue of adverse psycho-emotional health outcomes for people with SCI is important to consider given the prevalence of anxiety and depression amongst the cohort. For example, meta-analytic data have confirmed a depression point-prevalence rate of approximately 20%[7] , while an anxiety point-prevalence rate of approximately 30%[6].

The existence of adverse psycho-emotional health outcomes during the acute stage[4] is problematic as many people who experience an SCI spend an extended time in hospital rehabilitation environments, which have been characterised as unsatisfactory and detrimental to psycho-emotional health. [10,11] The adverse health outcomes experienced may, in turn, contribute to poorer functional rehabilitation outcomes, [12] and adversely impact quality of life in the long-term.

Interventions which aim to improve the psychological well-being of people receiving rehabilitation in hospital are critical. To date, a dearth of research has investigated the impact of participating in recreational interventions on the psycho-emotional health of people with SCI receiving rehabilitation in hospital.[13] Research has confirmed that spending a longer time participating in leisure outings – primarily in natural settings[13] - during inpatient rehabilitation is associated with higher functional rehabilitation outcomes at discharge. [14] Findings also suggest that the impact of participating in such activities can have an impact on psychological wellbeing up to 1 year post discharge.[15] Finally, evidence-based reviews have confirmed that (i) engaging with the natural environment can improve the psycho-emotional health of people who have a neurological disability, [16] and (ii) engaging with simulated natural environments evokes a physiological brain response aligned with relaxation.[17] These promising findings support the need for further research.[13]

Given the increasing use of virtual reality (VR) for the rehabilitation of people with traumatic injury, [18,19] and the efficacy of simulated environments to promote positive psycho-emotional health outcomes, [20-26] there is potential for the use of VR-produced simulated environments in hospital settings to promote the psycho-emotional health of people who have experienced injury. To date, only one study to date has investigated the use of natural environments delivered via VR to promote the psycho-emotional health of people with SCI in hospital.[27]

The case study (n=2) concluded that engaging with simulated environments via VR reduced the negative emotions (including anxiousness) of people with SCI.

The current study builds on the limited evidence-base investigating the impact of engaging with natural environments delivered via VR on the psycho-emotional health of people who have experienced an SCI and are receiving rehabilitation in hospital. The study aimed to answer the following questions:

RQ1. What is the impact of engaging with natural environments delivered via VR on the immediate mood of people with SCI in hospital?

RQ2. What is the impact of engaging with multiple VR sessions over a period of a week on the depressive symptoms of people with SCI in hospital?

The authors hypothesised that engaging with simulated natural environments would favourably impact immediate mood (as established by [20-26]), and reduce the depressive symptoms, of people with an SCI receiving rehabilitation.

Methods

Ethical approval to conduct this research was provided by both the Metro South Health Human Research Ethics Committee (protocol ID: 18/QPAH/425) and the Griffith University Human Research Ethics Committee (protocol ID: 2019/290).

Study Design

A randomized controlled design was employed where a treatment condition and control condition were tested over a period of two weeks. The treatment condition involved participation in up to three 20-minute VR sessions over three consecutive days during one week. The control condition involved regular rehabilitation practice over a week.

Participants and Recruitment

In June 2019, SCI inpatients from a specialist rehabilitation unit at a hospital in Australia, were invited to participate in the study. Eligibility criteria included (i) cognitive capacity to consent, (ii) being an adult, (iii) experiencing a traumatic or non-traumatic SCI, and (iv) having a rehabilitation plan in place with set goals. Cognitive capacity to consent was established by having a mini-mental state examination [MMSE] score of 18 or above. An a priori power analysis utilising G*Power 3.1[28] was conducted. Given a large effect size (.80), an alpha of .05 and a power of .80, a total sample size of 52 (26 for each group) was required to test for the difference between two independent group means using a two-tailed test. For this pilot study, all participants eligible for participation (n=37) were provided information and consent documentation by one of the study investigators. Participants had four days to review the information and consent materials and have any questions answered. After, participants were requested to provide written consent. In total, 24 participants provided consent. Participants were randomized to either Group 1 (n=10) or Group 2 (n=14) using the excel function 'randbetween'. Group 1 participants experienced the intervention during week 1, and the control during week 2, while Group 2 experienced the opposite.

Control Condition

During the control condition participants engaged in regular rehabilitation practice. Regular rehabilitation practice is dependent on an individual's rehabilitation goals but typically involves attending daily occupational therapy and physiotherapy sessions with specialised input from social work, psychology leisure therapy, and nursing professionals, alongside required specialist medical teams. The extent of input from distinct disciplines is dependent on the individual's injury level and rehabilitation goals. For example, someone with a cervical injury would have heavier input from occupational therapy given their upper limb rehabilitation needs whereas someone with a thoracic injury would have heavier input at the

physiotherapy gym given their need to develop manual wheelchair skills, strengthening, and endurance.

Treatment Condition

During the treatment condition, participants engaged in their regular rehabilitation practice with additional VR sessions. A diversity of virtual natural environments available via the Oculus Go VR headset were utilised throughout the three VR sessions. Each session was approximately twenty minutes. Table 1 details the environments experienced during each session.

[Insert Table 1 Here]

Measures

Demographic questions consisted of age, gender, injury level, injury severity (American Spinal Injury Association [ASIA] Impairment Scale), injury type (traumatic – due to trauma caused by motor vehicle accident, fall, or sporting injury, or non-traumatic - due to disease[29]), Aboriginal and/or Torres Strait Islander [ATSI] status, and time in hospital. Pre and post outcome data included the Patient Health Questionnaire – 8 (PHQ-8) [30] - a reliable measure of depressive symptom severity among people with SCI, [31] including people with SCI receiving rehabilitation in hospital. [32] Higher PHQ-8 scores are a measure of a higher level of depressive symptoms. Participants from both groups completed the PHQ-8 questionnaire at three time points: T_1 prior to the first condition, T_2 immediately after the first condition and prior to the second condition, and T_3 after the second condition. In the current study, the PHQ-8 demonstrated good reliability (baseline administration produced an alpha of .701).

In addition, participants completed three feeling intensity scales, prior to, and following each VR session. The feeling intensity scales were adapted versions of the Depression Intensity Scale Circles developed by Turner-Stokes, Kalmus, Hirani, Clegg [33] (with permission from

scale authors). Participants selected a circle across a six circle scale that best represented their feeling at a current moment. The feelings were anchored as indicated (i) sad/depressed to happy/content, (ii) anxious/nervous to calm/relaxed, and (iii) not feeling good to feeling good. The scales were scored such that a higher number was indicative of a more favourable feeling.

Data analysis

Planned comparison analyses were used to address the distinct research questions. IBM SPSS 25 was used for all analyses. In relation to RQ1, non-parametric inferential analyses were conducted to establish if there were significant differences in feeling intensity scale responses prior to and after each intervention session. Non-parametric inferential analyses were identified as opportune since ordinal data was used. Specifically, nine Wilcoxon Signed Ranks Tests were undertaken for each mood intensity response across each of the three VR interventions. Additionally, informed by Kerby[34], the matched-pairs rank biserial correlation statistic calculated via the simple difference method was used as a measure of effect size.

In relation to RQ2, analysis was guided by the approach utilised by Fleming, Sorinola, Roberts-Lewis, Wolfe, Wellwood, Newham [35] and involved between and within group-comparisons. A t-test confirmed that T_1 PHQ-8 values between groups were not significantly different $t(14.899) = .330$, $p = 0.746$. Given the sample size, testing for normal distribution was identified as not useful. Parametric tests were employed throughout analyses in line with RQ2. In relation to between-group comparisons, an independent sample t-test was conducted to establish if there was a significant difference between groups for T_{d1} and T_{d2} scores. Absolute values of Cohen's d were used as a measure of effect size. These planned analyses were conducted as the aim was to establish if significant differences in changes to depressive symptoms existed between groups experiencing the intervention and control.

In relation to within-group comparisons, two one-way repeated measures analysis of variance were conducted (one for Group 1 and Group 2) to test if a significant difference was apparent within each group due to time. Subsequent to a significant effect for time, pairwise comparisons were be conducted to establish the differences between distinct pairs.

Results

Participants

Participant demographics have been included in Table 2 and Figure 1 displays the Consolidated Standards for Reporting Trials flow diagram.

[Insert Figure 1 Here]

[Insert Table 2 Here]

RQ1: What is the impact of engaging with natural environments delivered via VR on the mood of people with spinal cord injury in hospital?

Descriptive statistics for pre and post mood intensity responses across all VR interventions are listed in Table 3, and Wilcoxon Signed-Ranks tests statistics are provided in Table 4. Wilcoxon Signed-Ranks tests indicated that after every VR session, participants' reported significantly higher levels of happiness and better mood, in addition to being significantly calmer. Matched-pairs rank biserial correlation values for mood intensity scores across VR Sessions 1 and 2 ranged from medium to large, while values for VR Session 3 mood intensity scores ranged from low to medium.

[Insert Table 3 Here]

[Insert Table 4 Here]

RQ2: What is the impact of engaging with multiple VR sessions over a period of a week on the depressive symptoms of people with spinal cord injury in hospital?

Descriptive statistics

Analyses are based on 6 participants in Group 1 and 10 participants in Group 2, due to incomplete data from 2 participants in each group. Mean PHQ-8 scores for each condition, across each time-period (as seen in table 5 and Figure 2) demonstrate lower PHQ-8 scores, for both groups, subsequent to participating in the intervention. The figure includes a line-graph where the mean PHQ-8 scores for each condition across each time-period is presented. As clarified by the table and figure, PHQ-8 scores were lower for both groups subsequent to participating in the intervention.

[Insert Table 5 Here]

[Insert Figure 2 Here]

Between-Group Comparisons

Mean difference score values and t-test coefficients are listed in Table 6. A t-test confirmed that the T_{d1} PHQ-8 values were significantly different between groups. Difference scores were significantly greater for Group 1 participants and the direction of the change suggests that the psycho-emotional health of Group 1 (intervention condition) had improved significantly compared to Group 2 (control condition). A second t-test confirmed that the T_{d2} PHQ-8 values were not significantly different between groups. While the direction of difference scores suggested that psycho-emotional health improved for the Group 2 (intervention condition), compared to Group 1 (control condition), the difference was not significant. The effect size of the difference in T_{d1} and T_{d2} values between groups was large and medium respectively.

Within-Group Comparisons

In relation to Group 1, Mauchly's test clarified that the assumption of sphericity had not been violated ($\chi2(2) = .579$, $p = .749$). The results showed that differences in PHQ-8 scores over time were non-significant ($F(2,10) = 3.114$, $p=.089$). In relation to Group 2, Mauchly's test clarified that the assumption of sphericity had not been violated ($\chi2(2) = .237$, $p = .888$). The results showed that differences in PHQ-8 scores overtime were non-significant ($F(2,18) = .190$, $p=.828$).

Discussion

The findings from this study suggest that engaging with natural environments delivered via VR had a favourable impact on the immediate mood of people with SCI receiving rehabilitation in hospital and psycho-emotional health in the short-term. Group mean differences in depression severity ratings were significant immediately post intervention (T1), although not at T2. Perhaps this finding is due to the residual impact of the VR sessions on Group 1, who had participated in sessions during the week prior. Further research is required to confirm these findings.

The findings from this study add knowledge to an under-researched area. Previously, Flores, Linehan, Todd, Hoffman [27] investigated the impact of engaging with multiple VR sessions which involved Dialectical Behavioral Therapy (DBT) on the immediate mood state of people (n=2) who had recently experienced an SCI and were receiving rehabilitation in hospital. Comparable to the current study, participants completed scales clarifying their level of depressive symptoms, nervousness, and emotional health prior to and after each session. While Flores, Linehan, Todd, Hoffman[27] focused on a psychological therapy (DBT) and involved engaging with a single simulated natural environment, in combination the findings support the notion that engaging with simulated natural environments can improve the short-term psycho-emotional consequences of experiencing SCI.

It is also important to acknowledge that favourable psycho-emotional health outcomes experienced by study participants may have been due to changes across other determinants of psycho-emotional health resulting from the intervention. For example, studies have established that people with SCI experience high levels of pain, and that a bi-directional relationship between pain and mood exists,[36] where increased perceived pain may be associated with poor mood outcomes, and/or adverse mood may be associated with perceiving a higher level of pain. This is important to consider as engaging with VR can reduce the perceived pain of people with an SCI. This is confirmed by a recent systematic review surrounding the efficacy of VR interventions to address the pain of people with an SCI.[37] Studies have also confirmed that viewing simulated natural environments delivered via VR can reduce the pain experienced by burn patients[38] and people undergoing dental procedures.[39] The current study did not measure perceived pain, consequently it is not possible to ascertain if a reduction in pain may have also had an impact on participant psycho-emotional health outcomes.

The current study adds findings to the area and confirms that simulated natural environments can promote favourable psycho-emotional health outcomes for people who have experienced a traumatic injury. A recent systematic review clarified that engaging with natural environments can have a favourable impact on the emotional health of people who have experienced a neurological disability.[16] The explanatory model, *Neurological Disability, Psychosocial Health and Nature Engagement* suggests that passive engagement – immersion in natural settings – promotes favourable emotional health via attention-restoration.

Directions for future research & practice

A growing body of research advocates for the use of innovative interventions and programs to promote psycho-emotional health outcomes amongst people with traumatic injury.[4,40]

Engaging with simulated natural environments delivered via VR may have a favourable impact on the immediate mood-state of people with SCI. Multiple sessions a week may impact depressive symptoms. The findings have clinical implications which are important to consider. In this regard, there is potential for simulated natural environments delivered via VR to be implemented into therapies offered as a part of traditional rehabilitation. For example, physiotherapy and occupational therapy programs may benefit from the use of VR delivered simulated natural environments where inpatients complete required therapeutic exercises in a virtual a natural setting. Such practices may simultaneously result in functional gains while improving psycho-emotional health. Clearly, it will be essential for research to investigate the efficacy of such approaches. Furthermore, future studies need to investigate how consistent engagement with simulated natural environments over the course of rehabilitation, impact psycho-emotional health consequences upon transition to the community, and, how engagement with simulated environments while in the community, can impact psycho-emotional health in the medium to long-term. This is especially important as research has already established that for people with SCI living in the community, (i) natural environments are amongst the least accessible places to frequent [41,42] and residing in communities with open greenspace is associated with higher perceived health status.[43]

Limitations

Given the distinct virtual reality experiences selected, it is not possible to make claims about the efficacy of diverse natural virtual environments outside of those utilised. As the environments included did not lend themselves to interaction (participants viewed environments without interacting with them), it is not possible to ascertain how interactive VR environments might impact psycho-emotional health outcomes. Additionally, demographic distinctions across participating groups need to be considered, as they may also have had an impact on findings. For example, Group 1 included no females, while

approaching 50 percent of Group 2 participants were female. Perhaps males were exceptionally responsive to the VR intervention, resulting in significant group differences in T_{d1} scores. Furthermore, the study did not account for cofounder measures (for example participant comorbidities) which may have also had an impact on findings. Finally, while significant findings are present, these should be taken with caution - particularly for findings in line with RQ2 between-groups analyses - given (i) the small sample size, and (ii) that 20% (n=4) of potential participants were excluded from these analyses due to missing data. It is unclear how much of an impact the missing data may have had. However, notwithstanding the need for further research, the findings from this pilot study provide preliminary evidence supporting the notion that the proposed program is promising.

Conclusion

To the knowledge of the authors this is the first study to investigate the impact of engaging with simulated natural environments delivered via VR on the psycho-emotional health of people with a SCI receiving rehabilitation in hospital. The study provides evidence to support the notion that VR interventions can promote favourable psycho-emotional health which, in turn, may positively impact on other health behaviours (for example, rehabilitation compliance). The findings support the idea that additional resources should be dedicated towards the delivery of simulated natural environments for inpatients within rehabilitation settings.

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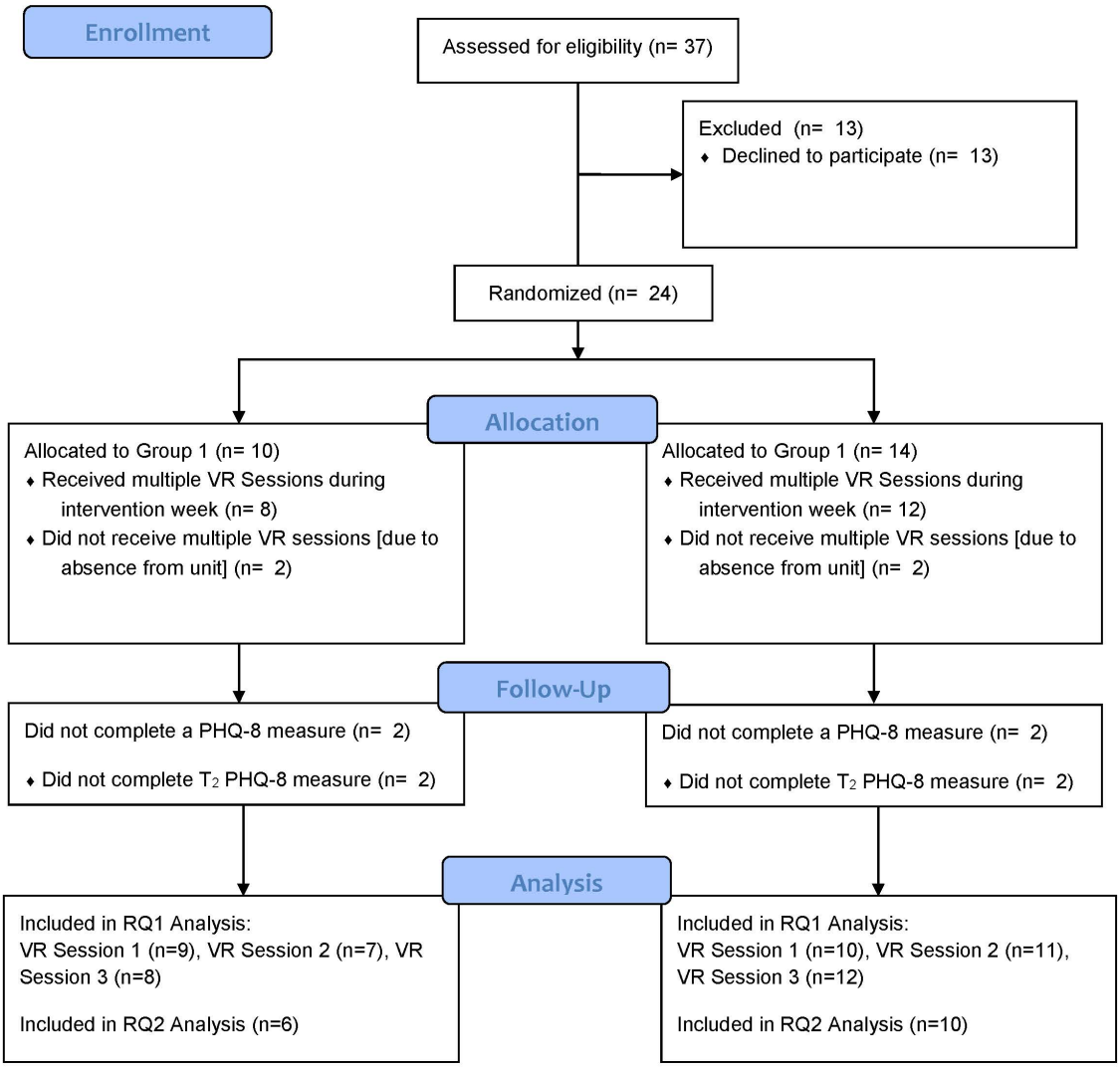

Figure 1: Consolidated Standards of Reporting Trials flow diagram

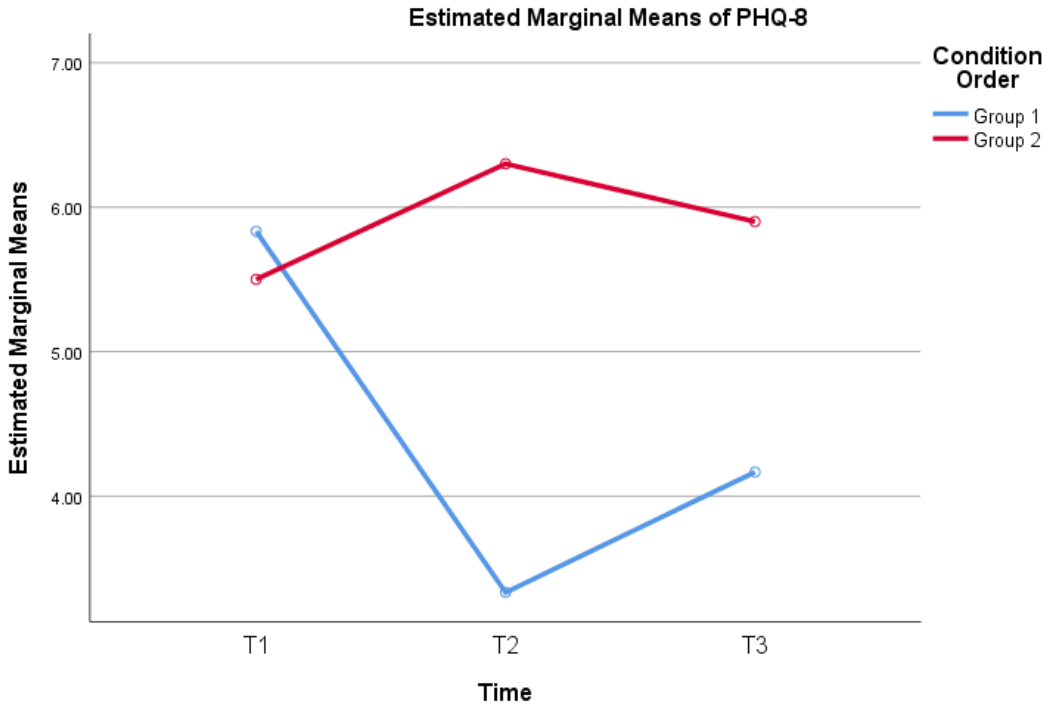

Figure 2: Line-graph of PHQ-8 scores for both groups

Table 5: Descriptive statistics for PHQ-8 scores across each time period

Time Period	Group	Mean	Std. Deviation	N
T1	Group 1	5.83	4.71	6
	Group 2	5.50	2.99	10
	Total	5.63	3.58	16
T2	Group 1	3.33	3.44	6
	Group 2	6.30	1.95	10
	Total	5.19	2.90	16
T3	Group 1	4.17	5.04	6
	Group 2	5.90	3.28	10
	Total	5.25	3.96	16

Table 1: Environments used within each session

Session Number	**Environments**
Session One	David Attenborough's Great Barrier Reef Dive
Session Two	National Geographic Dive through and Oil Rig Ecosystem National Geographic Orangutan School for Orphaned Babies National Geographic Bryce Canyon National Geographic Joshua Tree National Park
Session 3	National Geographic Polar Obsession National Geographic Underwater National Park National Geographic Victoria Falls Part 1 National Geographic Victoria Falls Part 2

Table 2: Participant demographics

Characteristic	Group 1 Frequency [Percent] or Mean [SD]	Group 2 Frequency [Percent] or Mean [SD]
Age (years)	56.20 [20.74]	48.00 [16.21]
Gender		
Male	10 [100]	6 [42.9]
Female	0 [0]	8 [57.1]
Aboriginal and/or Torres Strait Islander Status		
Yes	2 [20.0]	1 [7.1]
No	8 [80.0]	11 [78.6]
Missing		1 [7.1]
Relationship Status		
Married or de facto	7 [70.0]	6 [42.9]
Not married nor de facto	2 [20.0]	8 [57.1]
Missing	1 [10.0]	
Time since injury (days)	135.20 [63.64]	127.21 [79.51]
Time in hospital (days)	135.22 [63.92]	131.54 [103.30]
Injury Type		
Traumatic	9 [90.0]	8 [57.1]
Non-Traumatic	1 [10.0]	6 [42.9]
ASIA		
A	7 [70.0]	3 [21.4]
B	1 [10.0]	0 [0]
C	2 [20.0]	7 [50.0]
D	0 [0]	4 [28.6]
Injury Level		
C1-C3	2 [20.0]	0 [0]
C4-C5	3 [30.0]	3 [21.4]
C6-C8	2 [20.0]	3 [21.4]
T1-T6	2 [20.0]	1 [7.1]
T7-T11	0 [0]	2 [14.3]
T12-L1	1 [10.0]	5 [35.7]

Table 3: Mood intensity scale descriptive statistics

	N	Mean	Std. Deviation	Minimum	Maximum
VR Session 1					
Pre: Sad/Depressed - Happy/Content	19	3.58	1.26	2.00	6.00
Pre: Anxious/Nervous - Calm/Relaxed	19	3.84	1.46	2.00	6.00
Pre: Not Good - Good	19	3.84	1.38	2.00	6.00
Post: Sad/Depressed - Happy/Content	19	5.00	1.11	3.00	6.00
Post: Anxious/Nervous - Calm/Relaxed	19	5.11	1.05	3.00	6.00
Post: Not Good - Good	19	5.21	1.03	3.00	6.00
VR Session 2					
Pre: Sad/Depressed - Happy/Content	18	3.56	1.54	1.00	6.00
Pre: Anxious/Nervous - Calm/Relaxed	18	3.83	1.42	1.00	6.00
Pre: Not Good - Good	18	3.89	1.41	2.00	6.00
Post: Sad/Depressed - Happy/Content	18	5.22	1.06	2.00	6.00
Post: Anxious/Nervous - Calm/Relaxed	18	5.33	0.84	3.00	6.00
Post: Not Good - Good	18	5.39	0.92	3.00	6.00
VR Session 3					
Pre: Sad/Depressed - Happy/Content	20	4.20	1.24	1.00	6.00
Pre: Anxious/Nervous - Calm/Relaxed	20	4.60	1.23	2.00	6.00
Pre: Not Good - Good	20	4.70	1.22	3.00	6.00
Post: Sad/Depressed - Happy/Content	20	5.30	0.80	4.00	6.00
Post: Anxious/Nervous - Calm/Relaxed	20	5.35	0.81	4.00	6.00
Post: Not Good - Good	20	5.25	0.79	4.00	6.00

Table 4: Wilcoxon Signed-Ranks Test Statistics

	Matched-pairs rank-biserial correlation	Positive Ranks (number of participants who had a higher post score)	Negative Ranks (number of participants who had a higher pre score)	Tied Ranks (number of participants who had an equal pre and post score)	Z-Score	P-Value
VR Session 1						
Pre vs Post Sad/Depressed - Happy/Content	.74	14	0	5	-3.342	.001
Pre vs Post Anxious/Nervous - Calm/Relaxed	.63	12	0	7	-3.097	.002
Pre vs Post Not Good - Good	.74	14	0	5	-3.352	.001
VR Session 2						
Pre vs Post Sad/Depressed - Happy/Content	.78	14	0	4	-3.347	.001
Pre vs Post Anxious/Nervous - Calm/Relaxed	.67	12	0	6	-3.097	.002
Pre vs Post Not Good - Good	.67	12	0	6	-3.090	.002
VR Session 3						
Pre vs Post Sad/Depressed - Happy/Content	.65	14	1	5	-3.216	.001
Pre vs Post Anxious/Nervous - Calm/Relaxed	.4	10	2	8	-2.668	.008
Pre vs Post Not Good - Good	.4	10	2	8	-2.021	.043

*All Z-Scores based on negative ranks

Table 6: Between-Group Comparison Coefficients

PHQ-8 Difference Score	Group	N	Mean	Std. Deviation	Cohen's d	t	df	p-value
T_{d1}	Group 1	6	-2.50	2.07				
	Group 2	10	0.80	3.79	.84	-2.247	13.962	.041
T_{d2}	Group 1	6	0.83	2.48				
	Group 2	10	-0.40	4.09	.41	.751	13.966	.465

Absolute values of Cohen's d were used as a measure of effect size. The effect size of the difference in Td1 and Td2 values between groups was large and medium respectively.