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Virtual Reality Exposure Therapy for the Treatment of Dental Phobia: A Controlled Feasibility Study

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Background: Virtual reality exposure therapy (VRET) has been used to treat a variety of fears and phobias. **Aim**: To determine the feasibility (i.e. safety and efficacy) of using VRET to treat dental phobia. **Method:** Safety was evaluated by determining any adverse events or symptom exacerbation. Efficacy of VRET was evaluated by comparing the reduction in dental anxiety scores (measured 16 times within a 14-week study period, and at 6-month follow-up), and its behavioural effects with that of an informational pamphlet (IP) on ten randomized patients with dental phobia using a controlled multiple baseline design. Participants' heart rate response during VRET, and their experience post-VRET, were indexed. **Results:** No personal adverse events or symptom exacerbation occurred. Visual analysis and *post-hoc* intention-to-treat analysis showed a significantly greater decrease in dental anxiety scores [higher PND (percentage of non-overlap data) scores of 100% and lower POD (percentage of overlap data) of 0%, Modified Dental Anxiety Scale, F (1,8) = 8.61, p = 0.019, and Dental Fear Scale,

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F (1,8) = 10.53, p = 0.012], and behavioural avoidance in the VRET compared with the IP group [d = 4.2 and –1.4, respectively). There was no increase in average heart rate during VRET. Of the nine treatment completers, six (four from the VRET group and two from the IP group) no longer had dental phobia at 6-month follow-up. Four of the five VRET participants, but none of the IP participants, scheduled a dental treatment appointment following the intervention. **Conclusion:** VRET is a feasible alternative for patients with dental phobia.

Keywords: dental phobia, dental anxiety, Diagnostic and Statistical Manual of Mental Disorders, specific phobia, virtual reality exposure therapy

Introduction

Research suggests that about 25% of the population suffers from a fear of specific dental procedures, whereas about 4% fulfil the criteria for dental phobia (Oosterink et al., 2009). Because the resultant avoidance of dental treatment could have considerable impact on both oral and general health (Schuller et al., 2003), timely management of dental phobia is central to improving dental attendance and quality of life.

Recently, virtual reality exposure therapy (VRET) involving exposure to an individual's fear-provoking objects and situations using a computer-generated environment in a well-controlled graded manner (Krijn et al., 2004), has gained acceptance in the treatment of a wide variety of fears and specific phobias. To date, there are no controlled studies investigating the effect of VRET in treatment of dental phobia. The purpose of the present study was to determine the feasibility, in terms of safety and efficacy, of applying VRET for the treatment of dental phobia.

Method

Participants and design

The study protocol was approved by the ethical board of SEGi University, Malaysia (reference: EC01/14-01) in accordance with American Psychological Association code of research conduct. Participants were recruited from the out-patient service of the Oral Health Centre of SEGi University. Patients who had not visited the dentist during the past 12 months, or reported anxiety and avoidance of dental procedures or both, were screened for the presence of dental phobia using the Modified Dental Anxiety Scale (MDAS). Patients with a MDAS score $\geq$ 15 and who provided informed consent, were interviewed using the Phobia Checklist (Oosterink et al., 2009), and screened for inclusion and exclusion criteria (see online Fig. 1). Eligible participants (n = 10) were randomized (1:1 allocation ratio) to either the VRET condition or an informational pamphlet (IP) control condition.

Safety of using VRET was evaluated by determining any adverse events or symptom exacerbation after intervention. A non-concurrent multiple-baseline design across subjects was used to evaluate the efficacy of the interventions. The total duration of study was 14 weeks for all participants, with different baseline and follow-up durations. Participants from both groups were randomly assigned to one of the baseline periods (5, 6, 7, 8 and 9 weeks) after which the interventions were administered. After the intervention, all participants were followed up weekly until 14 weeks, and finally at 6 months (see online Table 1).

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The outcome measures of interest in this study were state anxiety, measured using a Visual Analogue Scale-Anxiety (VAS-A), dental trait anxiety, indexed by both the Modified Dental Anxiety Scale (MDAS) and the Dental Fear Scale (DFS), and a Behavioural Avoidance Test (BAT) (Raghav et al., 2016) (see online Table 2). The MDAS, DFS and VAS-A were recorded weekly during baseline, before and after the intervention, until 14 weeks after the intervention, and finally at 6-month follow-up. The BAT was administered twice: pre- and post-intervention (see online Table 3).

During the VRET intervention, participants were asked to rate their anxiety repeatedly from 0 to 10, on the Subjective Unit of Distress Scale (SUDS) (Raghav et al., 2016). Each situational cue was repeatedly administered until the participant reported a SUDS score ≤ 2, after which the next cue was introduced. Participants' heart rate was continuously monitored during VRET using a wrist-worn heart rate monitor. Post-VRET, the participants were observed for 15 min to preclude any adverse events, and were assessed for their quality of VR experience as well as their intentions to undergo VR therapy in future and revisiting for their dental treatment (see online Tables 2 and 3).

At 6-month follow-up all participants were re-evaluated for dental phobia using the Phobia Checklist and for any symptom exacerbation. We also determined the number of participants who scheduled a dental appointment following the intervention.

Interventions

VRET intervention[1]. VRET participants were seated in the dental chair and assisted in wearing the head-mounted device (HMD), and the heart rate (HR) wristband. The baseline HR was recorded for 10 min. The VR environment consisted of a three-dimensional (3D) stereoscopic scene of a virtual dental operatory. The participants were able to see their own virtual counterpart (participant avatar) and a virtual Caucasoid dentist avatar. After orienting the participants with VR environment for two minutes, situational cues enacted by the dentist avatar were introduced in the following order:

(1) Sitting passively on the dental chair (no tools).
(2) Inspection of the oral cavity using mouth mirror.
(3) Introduction of an injection.
(4) Introduction of drill without sound.
(5) Introduction of drill with sound.

Through scenarios 2 to 5, participants were requested to keep their mouth open. All participants received the therapy in one session.

Informational pamphlet group. The Informational Pamphlet (IP) contained standardized information compiled from the Academy of General Dentistry factsheet on dental anxiety. IP

[1] VRET was conducted using two networked computers of which the VR-simulator computer (Dell XPS-8700 desktop with 4th Generation Intel Core i7-4790 processor (8M Cache, up to 4.0 GHz) and ASUS NVIDIA GEFORCE GTX 750 TI OC 2GB GDDR5 graphic card) rendered the virtual environment; the other user-interface computer allowed the researcher to control and individualize the VR stimuli presented to the patient. An Oculus development kit 2 HMD (Head Mounted Display) with a resolution of 960X1080 per eye was used to immerse the participants in the VR dental environment. A Mio-link wristband was used to record the heart rate of the VRET participants in real-time during therapy.

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participants were seated in the same area where they completed the self-reported measures, and were given time to review the pamphlet in detail and ask the researcher questions related to their dental anxiety. More details about the VRET and the IP are reported elsewhere (Raghav et al., 2016).

Analytic strategy

Safety of using VRET was evaluated by noting any adverse events following therapy and any symptom exacerbation during the follow-up. Efficacy of VRET was compared with IP, by performing a visual analysis for the dependent measures VAS-A, MDAS and DFS prior to, during and after interventions and measuring changes relative to the baseline phase (Lane and Gast, 2014). BAT scores and BAT steps within the treatment conditions were evaluated with a paired *t*-test. The trends of mean scores of HR of the different VR scenarios were graphically plotted. Descriptive statistics were used to describe presence, realism and cyber sickness (nausea) experienced by the participants during the VRET session.

Results

All participants completed the study except one (IP participant), who did not respond to the mailed questionnaire after the ninth week of the study.

Mean scores, standard deviations and effect sizes, for the total sample and both conditions, on all variables and all measurements, are presented in Table 1.

Safety of VRET

No adverse events or symptom exacerbation were reported post-therapy. In addition, no participant dropped out in the VRET group.

Analyses for state anxiety and dental trait anxiety

Visual analysis suggests that VRET was associated with a greater reduction of VAS-A, MDAS and DFS scores compared with IP (see online Tables 4–6 and online Figs 2–4).

We performed a *post-hoc* intention-to-treat analysis on the dependent measures and alpha was set at 5%. A MANOVA showed a significant main effect of time, but no significant interaction between time and group. Subsequent univariate testing showed a significant decrease in mean score for the VAS-A, MDAS and DFS from pre-intervention to post-intervention. A significant condition by time interaction effect was found for MDAS and DFS resulting from the fact that MDAS and DFS scores showed a stronger decrease in the VRET condition. Independent-samples *t*-tests for mean VAS-A, MDAS and DFS scores revealed no significant differences between the groups. However, some of the comparisons showed quite large effect sizes in favour of the VRET group, in particular at follow-up (Table 1).

Behavioral avoidance

A paired-samples *t*-test comparing the pre- and post-intervention BAT scores, and number of steps the patient was able to tolerate, revealed statistically significant differences between

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Table 1. Mean scores, standard deviations and between subgroups effect sizes for the total sample, on all variables

Dental anxiety scores				
		VRET Mean (*SD*)	IP Mean (*SD*)	Effect size
Baseline	VAS-A	7.2 (1.4)	6.4 (0.8)	–0.66
	MDAS	21.2 (1.7)	19.2 (1.1)	–1.35
	DFS	69.0 (8.7)	67.2 (9.0)	–0.20
Pre-intervention	VAS-A	7.9 (1.1)	7.6 (1.5)	–0.22
	MDAS	21.2 (1.7)	20.4 (2.0)	–0.41
	DFS	71.6 (12.7)	65.2 (15.0)	–0.46
Post-intervention	VAS-A	4.2 (4.2)	6.0 (2.4)	0.52
	MDAS	14.2 (3.1)	18.6 (4.0)	1.22
	DFS	50.4 (8.5)	63.3 (16.4)	0.98
Follow-up	VAS-A	2.0 (1.2)	3.5 (2.0)	0.89
	MDAS	11.6 (1.6)	15.0 (3.3)	1.29
	DFS	38.2 (9.3)	55.5 (14.1)	1.44
Behavioural avoidance scores				
		Pre-intervention Mean (*SD*)	Post-intervention Mean (*SD*)	Effect size
VRET	BAT	41.2 (5.5)	12.8 (7.5)	4.2*
	BAT-Steps	3.2 (0.8)	4.4 (0.5)	–1.43*
IP	BAT	36.4 (4.9)	34.4 (6.0)	1.0
	BAT-Steps	3.2 (0.4)	3.4(0.5)	–0.4

*$p < 0.05$. VRET, virtual reality exposure therapy; IP, informational pamphlet; VAS-A, Visual Analogue Scale-Anxiety; MDAS, Modified Dental Anxiety Scale; DFS, Dental Fear Scale; BAT, Behavioural Avoidance Test; BAT-steps, Behavioural Avoidance Test-Steps.

pre- and post-scores with large Cohen's *d* effect sizes respectively in the VRET condition (Table 1) compared with the IP condition.

Heart rate measurement

Confrontation with the increasingly more anxiety-eliciting stimuli during VRET did not cause any apparent acceleration in mean HR during therapy (see online Fig. 5).

Virtual reality experience

All participants in the VRET condition experienced cybersickness (nausea), except one. However, all participants experienced moderate presence and realism and expressed their intentions to undergo similar therapy in the future, and to revisit the dental surgery for treatment.

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Presence of dental phobia

At 6-month follow-up, of the nine treatment completers, six (four from VRET group and two from IP group) participants no longer met the diagnostic criteria of dental phobia.

Dental attendance

Although all VRET participants showed their interest, four out of five scheduled appointments and underwent treatment, but none of the IP participants scheduled a dental treatment appointment following the intervention.

Discussion

This is the first controlled study that evaluated safety and efficacy of using VRET in dental phobic individuals. Conducting such a pilot study was important to determine any difficulties in timing of measurements and limitations of VRET prior to commissioning the randomized controlled trial. We measured both subjective and objective fear response of the VRET participants in the present report to determine the feasibility for conducting a randomized controlled trial.

The results suggest that VRET is a safe and acceptable treatment for dental phobia as we found no apparent increase in patients' heart rate and no participant dropped out during VRET. No symptom exacerbation was reported post-VRET. Furthermore, VRET was associated with a significant reduction in state anxiety, dental trait anxiety, and behavioural avoidance. It appeared that 6 months after the VRET intervention, the number of participants who no longer met the criteria of dental phobia was higher in the VRET group compared with the IP group. The findings of self-reported measures were substantiated by the majority of VRET participants (four out of five) scheduling appointments and undergoing dental procedures, such as scaling followed by extractions and fillings.

The significant decrease in behavioural avoidance observed in VRET participants is corroborated by the finding that more participants scheduled dental appointments within the 6-months follow-up after the intervention.

Reduction in anxiety within the VRET group could be attributed to the satisfactory presence experienced by the participants during the intervention. It is assumed that VRET facilitates emotional processing by activation of people's underlying fear structure through controlled confrontations with their fearful stimuli without aversive outcomes, and that one learns that the fear is unfounded, thereby adjusting negative, irrational predictions (Craske et al., 2014). This explanation is supported by the finding that a participant who experienced lower VR presence during VRET showed no reduction in dental trait anxiety at the end of the study.

Some limitations of this study should be mentioned. Firstly, a majority of participants who underwent VRET experienced cyber sickness (nausea) post-session, indicating the importance of putting effort into reducing cyber sickness to increase the applicability of VRET. Secondly, the study had a limited follow-up of 6 months, and a small sample size, clearly restricting the generalizability of the study results. Lastly, the use of Caucasoid dentist avatars in a Malaysian population could be a potential limitation.

In conclusion, the results of this multiple baseline study are a first indication that the use of VRET is a safe and an effective treatment for dental phobia.

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Supplementary material

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