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Affectional interactions with your animated child avatar can enhance wellbeing

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Introduction: The aim of this proof-of-concept study was to evaluate the efficacy of a new virtual reality (VR) platform for practising the Self-Attachment Technique (SAT) in a non-clinical population. The growing prevalence of mental health problems underscores the urgent need for scalable and effective interventions. SAT is a self-administered psychotherapeutic technique where the individual creates an affectional bond with their childhood self and vows to re-raise this child to emotional wellbeing. Digital technologies like VR and avatars can naturally enhance SAT by improving imaginative interactions with the childhood self.

Methods: Over an 8-week period, participants practised the SAT exercises either by animating their personalised childhood avatar into different emotional states in VR or by imaginatively using their childhood photos. Participants' measurements were collected before and after the intervention as well as at 3-month follow-up, and analysed to understand whether changes over time, in the areas of wellbeing, self-compassion and psychological capital, are significant.

Results: Overall, participants experienced significant improvement in wellbeing (primary outcome) with large effect size ($r = 0.86$). Further exploratory analysis of our findings indicated that the effect of VR ($d = 1.12$) was better compared to the childhood photos ($d = 0.47$). Qualitative evidence from the present study suggested that the intervention had a positive impact on participants' daily lives.

Discussion: This study showed that practising SAT using the participant's childhood avatar in a virtual environment has potential for enduring effects that need to be validated in future randomised trials.

KEYWORDS

self-attachment, virtual reality, self-compassion, psychological capital, non-clinical trial, reparenting, bonding, 8-week intervention

1 Introduction

The Self-Attachment Technique (SAT) (Edalat, 2015; 2017; Cittern and Edalat, 2017) is a relatively new psychological intervention informed by attachment theory, as introduced by John Bowlby and Mary Ainsworth (Bowlby, 2008; 1973; 1998; Ainsworth et al., 2015). SAT reformulates optimal parent/child interactions—comprehensively studied in attachment theory over the past several decades—as a self-administered intervention.

The individual simultaneously takes the role of a "good enough" care-giving parent (Winnicott, 1953) and a care-seeking child. To make this meaningful and tangible, the individual is conceived of as two actors: an adult self, representing their more rational self, dominant when they are stress-free, and a childhood self, representing their emotional world, depicted by their childhood photos and dominant when they are overly stressed.

A pilot study to evaluate the efficacy of SAT to treat chronic depression and/or anxiety in Iranian women using childhood photos obtained a large effect size (Edalat et al., 2022). Thirty women suffering from clinical depression and/or anxiety for at least 3 years had eight face-to-face sessions of SAT intervention with a therapist over a period of 12 weeks, with four weekly sessions followed by four fortnightly sessions. The PHQ-9 and GAD-7 questionnaires were used in pre-test, post-test and at 3-month follow-up (Plummer et al., 2016; Negeri et al., 2021). The change in anxiety level between pre-test and post-test was significant, with Cohen's d effect size of 2.5. The change in anxiety between pre-test and follow-up test had a Cohen's d effect size of 3.5. For depression, the changes between pre-test and post-test, as well as between pre-test and follow-up, were significant with Cohen's d effect sizes of 2.3 and 3.1 respectively.

Virtual Reality (VR) presents a natural medium for practising the adult/child interactive exercises of SAT by creating a child avatar from the childhood photo of the participant, first envisaged by Cittern et al. (Cittern et al., 2017). The emergence of VR technology in the past 2 decades has significantly enhanced many areas of human activities, including psychological interventions (Slater and Sanchez-Vives, 2016). Its huge potential to treat some mental illness and strengthen wellbeing has been investigated by many research groups across the globe (Powers and Emmelkamp, 2008; D'Cunha et al., 2019; Freeman et al., 2017). This technology has been transformative in alleviating several forms of phobias, psychosis and post-traumatic stress disorder (PTSD) through VR exposure therapy combined with cognitive enhancement techniques (Brown et al., 2022; Freeman et al., 2022; Difede et al., 2022; Garety et al., 2021; Rus-Calafell et al., 2022; O'Brien et al., 2021). In particular, Avatar therapy has shown to be significantly more efficacious than simple counselling in treating persistent auditory verbal hallucinations (Craig et al., 2018). The results in this area have been so promising that a recent VR implementation in the treatment of phobias and psychosis has been named "gameChange" by the researching team (Freeman et al., 2022; Brown et al., 2022). VR is now used not just to simulate real environments but to experience scenarios which step beyond reality and cannot be physically attained; this aspect of VR has been described as an "unreality simulator" (Slater and Sanchez-Vives, 2016) and an "advanced imaginal system" (Riva et al., 2016).

VR-based SAT was considered, with a basic framework designed using Oculus Rift and Avatar SDK to generate the photorealistic 3D head for the child avatar (Cittern et al., 2017; Ghaznavi et al., 2019). In a follow-up study, a low-end version of the platform using Google Cardboard and an Android application was implemented which employed Cardboard's gaze controller to enable the participant to select the emotional state of their child avatar to be happy, sad or neutral (Ghaznavi et al., 2020). A subsequent study was conducted to evaluate a high-end version of the VR environment, which was equipped with a virtual agent, a dialogue manager and a platform for audio and text detection of the user's emotion (Polydorou and Edalat, 2021). The virtual agent engages with the participant and, after detecting their emotion and its validation by them, makes suggestions for the user to undertake an appropriate SAT exercise. Five volunteers, all in their mid-twenties, evaluated the platform by interacting with it in two 30-min sessions separated by seven to 10 days. In one session, a generic child avatar was employed, whereas in the other session, an avatar created from the participant's own childhood photo was used. Participants reported that interaction with their own childhood avatar was more emotionally engaging and made them feel more compassionate than interaction with the generic avatar. This trial had been motivated by two VR studies in which the participant expressed compassion to a generic child avatar and was embodied in a child avatar, who in turn received compassion from a generic adult (Falconer et al., 2014; 2016).

The outcome of these experiments led us to undertake an 8-week VR-based human trial for the SAT protocol in a non-clinical population. Our hypothesis is that practising the SAT protocol with the use of childhood avatars and VR can potentially induce change in the individual in the primary area of wellbeing and the secondary areas of self-compassion and psychological capital. We have also explored whether interaction with one's childhood avatar can lead to transformative self-change, a paradigm envisioned in Riva's paper on VR in psychotherapy (Riva, 2005).

The present proof-of-concept study demonstrated the feasibility and potential utility of VR technology in administering SAT, showing significant improvements in wellbeing, self-compassion, and psychological capital, which were sustained 3 months post-intervention. Notably, using avatars in conjunction with photos resulted in greater benefits compared to photos alone. Overall, the study's results underscored the potential long-term positive effects of SAT using VR, paving the way for larger, more rigorous studies to further evaluate its effectiveness in diverse populations.

2 Materials and methods

2.1 Study design

We designed a repeated measurement experiment using time as a single factor. Participants learned how to practice the SAT exercises in eight weekly online Zoom group sessions of 90 min each. During these sessions, participants had the opportunity to address any questions and make comments regarding the exercises from the previous week. Then, the exercises for the following week were presented to them and they had the chance to ask further questions regarding the protocol.

Participants were expected to individually practice the exercises for at least 15 min twice a day throughout the 8 weeks of the intervention. They were instructed to maintain a daily personal diary to document their practice, serving as a means to track adherence to the exercises. We deliberately avoided offering material compensation to ensure that the participants maintained intrinsic motivation, i.e., the desire for self-change.

Participants were asked to complete three standard self-rating questionnaires (PERMA-Profiler, SOCS-S, and CPC-12R) through the Qualtrics platform on three occasions: before the intervention

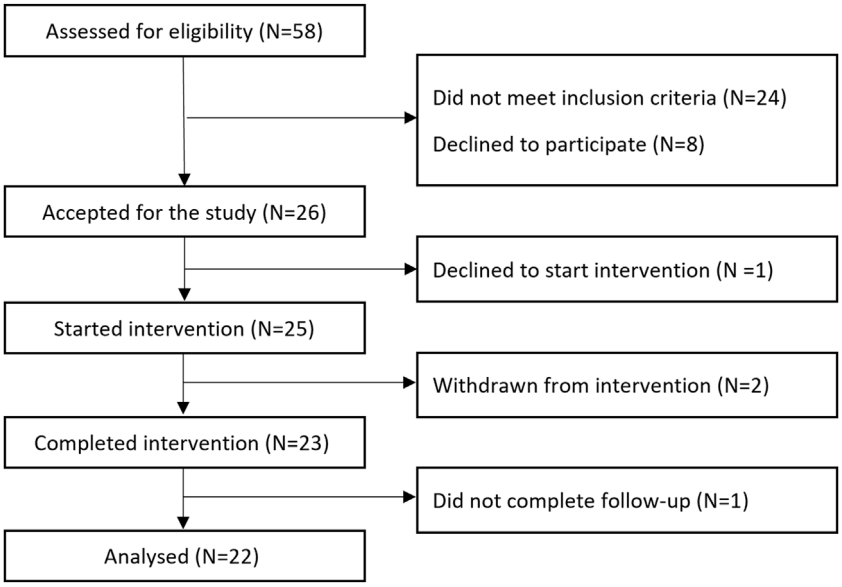

FIGURE 1
Consort diagram.

(pre-test), following completion after 8 weeks (post-test), and in a 3-month follow-up (follow-up test). The findings of an earlier feasibility study during the COVID-19 pandemic lockdown have been the basis of the choice of these three outcome measures.

The primary outcome measure of the study was considered to be wellbeing as rated using the PERMA-Profiler questionnaire. The PERMA-Profiler is a brief measure of flourishing (wellbeing) in relation to Positive emotion, Engagement, Relationships, Meaning, and Accomplishment (PERMA). It has been widely used, with acceptable psychometric properties and has scored highly for convergent and divergent validity (Butler and Kern, 2016). The secondary outcome measures were self-compassion and psychological capital. To measure self-compassion, we used the Sussex-Oxford Compassion for the Self Scale (SOCS-S), with robust psychometric properties and proven validity (Gu et al., 2020). For psychological capital, we employed the Compound Psychological Capital Scale (CPC-12R), which measures hope, self-efficacy, resilience, and optimism with adequate psychometric properties (Dudasova et al., 2021).

2.2 Participants

We recruited volunteers from the non-clinical population through various channels, including the Imperial College London website, social media platforms, and contacts of students and investigators. To include potential volunteers, we screened them using the GAD-7, PHQ-9, and WEMWBS scales. The cutoff scores used for these scales were as follows: PHQ-9 and GAD-7 scores less than 15 (i.e., at most, moderate levels of anxiety and depression) and normal mental wellbeing as measured by WEMWBS. Additionally, individuals were required to be fluent in English, aged between 20 and 65, and located in Europe or North America. We accepted all applicants who met these inclusion criteria. Screening data can be found in the Supplementary Material.

A power analysis based on i) expected moderate effect size of 0.65 for the primary outcome, ii) statistical power equal to 0.8, iii) acceptable level of significance $p < .05$, and iv) 15% dropout rate, suggested a sample size of at least 25 people. After excluding non-eligible volunteers, we started the intervention with 25 participants. Two participants dropped out during the third week due to changing personal circumstances, and one participant did not complete the follow-up evaluation. As a result, 22 participants (13 females and 9 males) completed all stages of the intervention with average age 41.6 (std = 12.5). Only these 22 people were included in the analysis. The consort diagram in Figure 1 shows the recruitment process in more detail.

2.3 VR platform

We created a mobile VR app specifically for this study for both Android and iOS operating systems, which could be operated with a Google Cardboard VR device, as shown in Figure 2. The virtual environment (VE), shown in Figure 3, featured a personalised child avatar that the user could observe and interact with from a third-person perspective (either standing or seated). The personalised look-alike child avatar was created from the favourite childhood photo of the user, based on Avatar SDK[1]. To practice the SAT protocol, the user could animate their childhood avatar into seven basic emotional states: happy, sad, angry, fearful, disgusted, surprised and neutral, as depicted in Figure 4. Another key

1 https://avatarsdk.com/

FIGURE 2
This example illustrates how participants were wearing the Google Cardboard VR headset device.

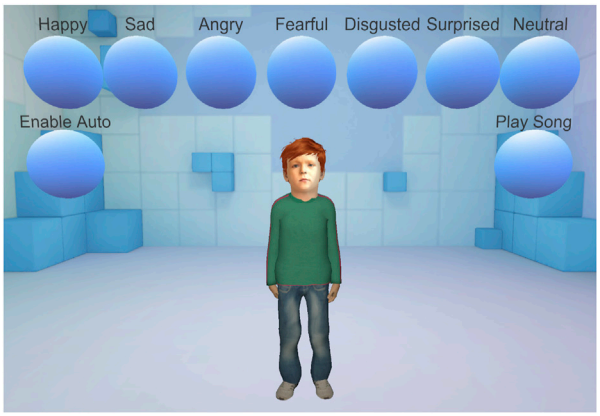

FIGURE 3
Virtual Environment with customised child avatar and emotion selections.

feature for practising SAT was a procedure in which the user could change the facial emotion of the avatar from any negative emotion to happy, by staring at the avatar for 30 s. By further staring for another 30 s, the avatar would start to dance to the user's happy favourite song, as demonstrated in Figure 5.

We asked participants to rate, on a Likert scale from 1 to 7, how proficient they were in interacting with the virtual environment at the end of the intervention, and how immersed they felt in the environment. In addition, participants were asked to rate, on a Likert scale from 1 to 5, their agreement with the statements that the mobile app was easy to use, and the environment was effectively interactive.

2.4 SAT protocol

The core of the SAT protocol consists of the following. The adult self establishes first a compassionate connection with their childhood self, using their favourite childhood photos or virtual avatar. Then, by reciting their favourite love and happy songs, while looking at their favourite childhood photo and focusing on what they may like about their childhood, the adult self creates a passionate, imaginative bond with that child. A vow is then made by the adult self to look after the child whenever the child is in distress. This means that whenever the individual is overwhelmed or affected by negative emotions, the adult externalises these negative emotions to the child and takes up the challenge of comforting the distressed child.

In practice, the adult plays this comforting role by emulating the actions of a "good enough" primary caregiver when their child is distressed. Therefore, the SAT protocol is a double role-playing game where the individual creates, by the initiative of their adult self, a compassionate attitude towards their childhood self, represented either by a favourite and a non-favourite childhood photo or by the photo-realistic avatar from a third-person perspective. The general description of the core protocol provided to the participants is as follows.

1. Look at your most and least favourite childhood photos and the childhood avatar with different emotions, and use your power of imagination to interact with your childhood self.
2. Establish a compassionate connection with your childhood self by focusing attention on your photos and avatar that you can animate into any of the seven basic emotions (happy, sad, angry, fearful, disgusted, surprised, neutral).

FIGURE 4
Basic emotions (happy, sad, angry, fearful, disgusted, surprised, neutral) displayed on avatar.

FIGURE 5
Avatar dance animation.

3. Use your favourite song, that expresses compassion and affection for your childhood self, to create a passionate and loving bond with your childhood self by repeatedly reciting the song while looking at your favourite photo and happy avatar.
4. Commit to re-raise your childhood self to enhanced social and emotional maturity.
5. Project your positive and negative emotions, respectively, onto your corresponding photos and on your corresponding animated avatar.
6. Maximise your positive emotions by engaging with your favourite photo and happy avatar through singing, dancing and laughter.
7. Minimise your negative emotions as follows. First project them onto your non-favourite photo and the corresponding animated avatar. Then engage in self-hugging, head-neck massage, verbal assurance and affirmations, while imagining these actions are performed on your childhood self.

2.5 Statistical analysis

Each of the study measures (PERMA, SOCS-S, CPC-12R) was the dependent variable and the data collection time (pre-test, post-test, follow-up test) was the independent variable. Therefore, we performed repeated measurement comparisons between pre-test and post-test measurements (Pre/Post) and between pre-test and follow-up test measurements (Pre/Follow-up). For this data analysis, we used Python 3.8.10 with the following libraries: pingouin 0.5.3 and researchpy 0.3.5.

We used paired t-tests for each comparison to investigate whether effects over time were statistically significant ($p < .05$). Due to the normality assumption, we used the Shapiro–Wilk test to check whether the difference between the paired samples was normally distributed. In case normality was not satisfied, we used Wilcoxon signed-rank test to prove the significance of the results ($p < .05$).

When the samples were normally distributed and paired t-tests were used, we calculated Cohen's d as a measure of effect size. Specifically, we calculated the Cohen's d average (d_{av}) which is appropriate for correlated (repeated) measurements (Lakens, 2013). Due to the small sample size, d_{av} can be biased; to find the unbiased version of d_{av}, we used the Hedge's correction factor given by,

$$1 - \frac{3}{4(n_1 + n_2) - 9},$$

where n_1 and n_2 are the number of subjects in each group (for repeated measures $n_1 = n_2$). The effect size was considered to be small for d equal to 0.2, medium for 0.5 and large for 0.8.

When normality was not satisfied and thus Wilcoxon signed-rank test is used, we calculated the matched-pairs rank-biserial correlation (r) (Kerby, 2014) as a measure of the effect size. The effect size is then considered to be small for r equal to 0.1, medium for 0.3 and large for 0.5.

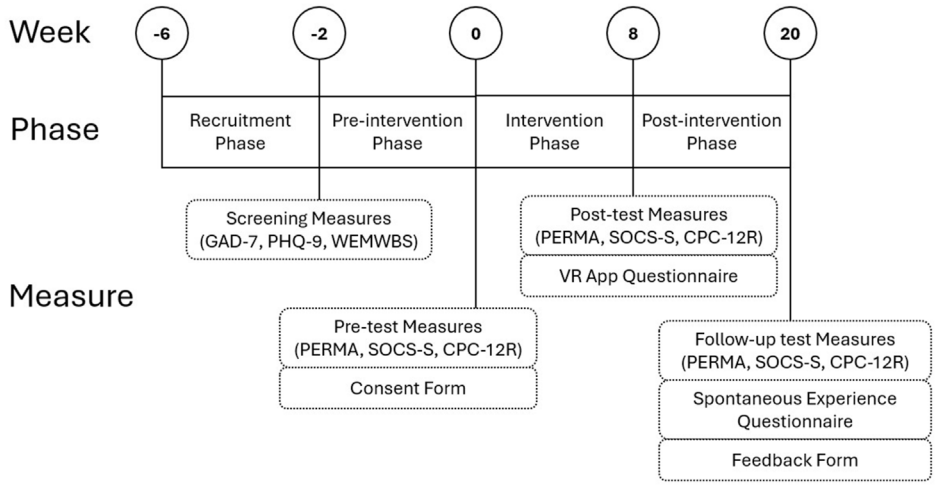

FIGURE 6
Study phases and measures' time-points diagram.

2.6 Study phases

The diagram in Figure 6 illustrates the distinct phases of the study. The Recruitment Phase involved volunteers applying to participate in and receiving comprehensive information about the study. During the Pre-intervention Phase, volunteers underwent screening to select suitable participants who were given the opportunity to ask questions about the study during Zoom meetings. The Intervention Phase comprised the active participation of selected individuals in the 8-week SAT intervention, practising of the SAT protocol using the VR platform. The Post-intervention Phase involved no direct interaction with the participants. The diagram also denotes the time-points of measurement, where "week 0" signifies the start of the intervention.

2.7 Ethical approval

The study was granted an ethical approval from the Science Engineering Technology Research Ethics Committee at Imperial College London (ICREC/SETREC reference number 21IC7351). All experiments were performed in accordance with relevant guidelines and regulations, and informed consent was obtained from all participants.

3 Results

The results for the main analysis are presented for each of the outcomes (PERMA, SOCS-S, CPC-12R). Some exploratory analysis that was not part of the design was carried out based on some observations after the study. Despite the significant time commitment (at least 30-min practice required daily for 8 weeks and weekly group sessions lasting 90 min each), the dropout rate was low (12%).

3.1 Main analysis

The results of the main analysis (N = 22) for the primary outcome and the two secondary outcomes can be found in Table 1. The analysis showed significant improvement in PERMA scores between pre-test (*median* = 6.78) and post-test (*median* = 7.94) with large effect size, $Z = 3.38$, $p = .001$, $r = 0.86$. This improvement was maintained at 3-month follow-up as the test indicated significant improvement in scores between pre-test (*mean* = 6.70, *std* = 1.19) and follow-up test (*mean* = 7.54, *std* = 0.98) with medium effect size, $t(21) = 3.42$, $p = .003$, $d = 0.75$. The results for the SOCS-S measurement showed significant increase in self-compassion between pre-test (*median* = 73.5) and post-test (*median* = 86) with large effect size, $Z = 2.55$, $p = .009$, $r = 0.62$. This increase in self-compassion was significant at 3-month follow-up (*mean* = 81.4, *std* = 11.0) compared to pre-test (*mean* = 72.7, *std* = 11.0) with medium effect size, $t(21) = 3.78$, $p = .001$, $d = 0.78$. Significant results were observed for CPC-12R scale as the statistical test indicated that the increase in psychological capital was significant between pre-test (*mean* = 55.6, *std* = 9.9) and post-test (*mean* = 60.8, *std* = 7.23) with medium effect size, $t(21) = 3.3$, $p = .003$, $d = 0.59$. This significant result was maintained at 3-month follow-up with large effect size $Z = 2.53$, $p = .012$, $r = 0.68$.

3.2 Exploratory analysis: compliance

During the study, participants were tasked with practising the SAT exercises daily and maintaining a brief summary in their personal diaries. This summary included the time spent for each exercises as well as any other personal comment. Participants were instructed to engage in the exercises for a minimum of 30 min daily, with the diary servin g as a means to verify adherence to this minimum dosage. Upon reviewing the diaries, it was found that 18 out of the 22 participants demonstrated compliance with the

TABLE 1 Main statistical analysis for primary and secondary outcomes: N = number of subjects, t-value = t-test statistic, ES (d) = Effect Size (unbiased Cohen's d average), Z-value = Z-statistic of the Wilcoxon signed-rank test, ES (r) = Effect Size (Matched-pairs rank-biserial correlation), *p*-value = significance value.

Main analysis (N = 22)	Comparison	t-value	ES (d)	Z-value	ES (r)	*p*-value
PERMA	Pre/Post			3.38	0.86	.001
	Pre/Follow-up	3.42	0.75			.003
SOCS-S	Pre/Post			2.55	0.62	.009
	Pre/Follow-up	3.78	0.78			.001
CPC-12R	Pre/Post	3.30	0.59			.003
	Pre/Follow-up			2.53	0.68	.012

TABLE 2 Exploratory analysis for compliant participants: N = number of subjects, t-value = t-test statistic, ES (d) = Effect Size (unbiased Cohen's d average), Z-value = Z-statistic of the Wilcoxon signed-rank test, ES (r) = Effect Size (Matched-pairs rank-biserial correlation), *p*-value = significance value.

Compliance (N = 18)	Comparison	t-value	ES (d)	Z-value	ES (r)	*p*-value
PERMA	Pre/Post			3.34	0.92	.001
	Pre/Follow-up	3.93	0.98			.001
SOCS-S	Pre/Post			2.33	0.63	.018
	Pre/Follow-up	5.27	1.03			< .001
CPC-12R	Pre/Post	2.90	0.60			.010
	Pre/Follow-up			2.45	0.72	.016

minimum dosage over the 8-week period. By observing the results of these 18 participants and those of the entire participant pool, our aim was to get an insight of the adherence to the minimum dosage. While it's important to note that this subset of participants cannot be statistically compared with the entire group due to group overlap, we have presented their results separately in Table 2.

The result of the compliant participants for the wellbeing score (PERMA) was significant between pre-test (*median* = 6.66) and post-test (*median* = 8.06) with large effect size, $Z = 3.34$, $p = .001$, $r = 0.92$. Significant improvement with large effect size was also observed between pre-test (*mean* = 6.66, *std* = 1.18) and follow-up test (*mean* = 7.70, *std* = 0.92), $t(17) = 3.93$, $p = .001$, $d = 0.98$. The results also showed significant large effect in self-compassion scores both between pre-test (*median* = 73.5) and post-test (*median* = 88.5), $Z = 2.33$, $p = .018$, $r = 0.63$, and between pre-test (*mean* = 73.1, *std* = 9.2) and follow-up test (*mean* = 83.1, *std* = 9.7), $t(17) = 5.27$, $p < .001$, $d = 1.03$. Regarding CPC-12R measurement, a significant result also was observed between pre-test (*mean* = 59.8, *std* = 6.79) and post-test (*mean* = 61.4, *std* = 7.26) with medium effect size, $t(17) = 2.9$, $p = .01$, $d = 0.6$. This significant result was maintained at 3-month follow-up with large effect size, $Z = 2.45$, $p = .016$, $r = 0.72$.

3.3 Exploratory analysis: avatar and photo users

As previously explained, the participants were presented with the choice to engage in the SAT exercises utilising either their personal photos or avatars. This flexibility did not restrict them from practising with both options; some exercises were performed using the photos, while others using the avatar. Upon examining the participants' diaries, it was evident that among the 22 participants, 11 individuals reported feeling more connected with their avatars and tended to use them more frequently than their photos, although they occasionally utilised the photos as well. On the other hand, the remaining 11 participants did not experience a sense of connection with their avatars, leading them to exclusively use their photos. This unexpected divergence in preferences emerged during the study. Consequently, we computed comparable statistics for both sets of participants to gain insights into the potential advantages of avatar usage, aiming to inform the design of future trials. We refer to those two sets of participants as avatar users and photo users, and the results are presented in Tables 3, 4 respectively.

The test for the avatar users demonstrated significant improvement in PERMA between pre-test (*mean* = 6.85, *std* = 1.23) and post-test (*mean* = 8.14, *std* = 1.00) with large effect size, $t(10) = 2.9$, $p = .016$, $d = 1.12$ and similarly between pre-test (*mean* = 6.85, *std* = 1.23) and follow-up test (*mean* = 8.05, *std* = 0.65) with large effect size, $t(10) = 3.35$, $p = .007$, $d = 1.23$. On the other hand, the only significant result for the participants that used only photos was between the pre-test scores (*mean* = 6.56, *std* = 1.2) and post-test scores (*mean* = 7.18, *std* = 1.37) with small effect size, $t(10) = 2.9$, $p = .016$, $d = 0.47$.

The avatar users' test indicated significant increase with large effect size in self-compassion between pre-test (*mean* = 74.6, *std* = 9.1) and post-test (*mean* = 85.9, *std* = 13.8), $t(10) = 3.05$,

TABLE 3 Exploratory analysis for participants who used their avatar: N = number of subjects, t-value = t-test statistic, ES (d) = Effect Size (unbiased Cohen's d average), Z-value = Z-statistic of the Wilcoxon signed-rank test, ES (r) = Effect Size (Matched-pairs rank-biserial correlation), *p*-value = significance value.

Avavar users (N = 11)	Comparison	t-value	ES (d)	Z-value	ES (r)	*p*-value
PERMA	Pre/Post	2.90	1.12			.016
	Pre/Follow-up	3.35	1.23			.007
SOCS-S	Pre/Post	3.05	0.95			.012
	Pre/Follow-up	3.64	1.11			.005
CPC-12R	Pre/Post	2.77	0.79			.020
	Pre/Follow-up	2.66	0.71			.024

TABLE 4 Exploratory analysis for participants who used only their photos: N = number of subjects, t-value = t-test statistic, ES (d) = Effect Size (unbiased Cohen's d average), Z-value = Z-statistic of the Wilcoxon signed-rank test, ES (r) = Effect Size (Matched-pairs rank-biserial correlation), *p*-value = significance value.

Photo users (N = 11)	Comparison	t-value	ES (d)	Z-value	ES (r)	*p*-value
PERMA	Pre/Post	2.90	0.47			0.016
	Pre/Follow-up	1.52	0.41			0.159
SOCS-S	Pre/Post			1.07	0.36	0.320
	Pre/Follow-up	1.87	0.53			0.091
CPC-12R	Pre/Post	2.49	0.33			0.032
	Pre/Follow-up	1.50	0.23			0.165

$p = .012$, $d = 0.95$ as well as between pre-test and follow-up ($mean = 85.3$, $std = 9.5$), $t(10) = 3.64$, $p = .005$, $d = 1.11$. The pre-test to post-test and pre-test to follow-up results were again non-significant for the photo users. More results on the sub-scales of PERMA and SOCS-S questionnaires can be found in the Supplementary Material.

Regarding the CPC-12R measurement for the photo users, the test showed that the post-test scores ($mean = 58.7$, $std = 7.25$) were significantly higher than the pre-test scores ($mean = 56.2$, $std = 7.77$) with small effect size, $t(10) = 2.49$, $p = .032$, $d = 0.33$. The pre-test to follow-up test comparison was not significant. On the other hand, the test for the avatar users demonstrated medium effect size between pre-test ($mean = 55$, $std = 12$) and post-test ($mean = 62.9$, $std = 6.93$), $t(10) = 2.77$, $p = .02$, $d = 0.79$, as well as between pre-test ($mean = 55$, $std = 12$) and follow-up test ($mean = 61.6$, $std = 5.82$), $t(10) = 2.66$, $p = .024$, $d = 0.71$.

3.4 VR app

On the scale 1 to 7, avatar users on average felt highly proficient ($mean = 5.27$, $std = 1.66$) and felt highly immersed ($mean = 5.36$, $std = 1.77$) in the environment. They rated the functionalities of the platform on the same scale with the following results: i) Emotion animation ($mean = 5.18$, $std = 0.94$), ii) Auto-emotion ($mean = 6.09$, $std = 1.08$), iii) Song ($mean = 5.91$, $std = 1.08$) and iv) Dancing animation ($mean = 5.82$, $std = 1.40$). Finally, on the scale 1 to 5 they agreed on the ease of use ($mean = 4.27$, $std = 0.75$) and the interactive environment ($mean = 4.36$, $std = 0.98$).

3.5 Spontaneous experience

Before the follow-up test, several participants reported that they experienced spontaneous recall of the image of their childhood photo or avatar during the 3-month period following the completion of the 8-week intervention. Thus, we formulated a new questionnaire to examine whether this was a common experience. Participants were asked to indicate whether this spontaneous experience took place, the context in which it occurred, and the frequency and the emotional impact of the recall. The questionnaire aimed to provide insight into such an experience in order to be formally evaluated in a future trial.

The collective results of the spontaneous experience questionnaire showed that among all participants (N = 22), 82% (N = 18) had such experience with either their avatars or photos at least once per week during the 3 months period. One-third of participants (N = 6) experienced both the avatar and the photos occasionally (at least once per week). The percentage of people who had this experience with the avatar was 45% (N = 10). Out of these 10 participants, 9 experienced positive mood change after any spontaneous recall of their avatar while the other participant had no emotional change. On the other hand, the childhood photos occasionally came to mind in 64% of participants (N = 14). From those, 12 had positive mood change, 1 had no change and 1 experienced negative change.

4 Discussion

This proof-of-concept study demonstrates the feasibility and potential utility of VR technology in administering SAT. Our

study has shown that SAT has the potential to improve wellbeing, self-compassion and psychological capital. By providing initial evidence for the benefits of this approach, our study can serve as a basis for further research and development in the field. The results and the unexpected findings of this study can be used to design and develop larger and more rigorous studies with control groups to further evaluate the potential of VR technology in practising SAT and investigate its robustness and effectiveness in different populations.

Our primary analysis showed significant positive changes across all evaluated outcomes (wellbeing, self-compassion, and psychological capital) at the end of the intervention. Notably, these positive changes were sustained 3 months post-intervention, suggesting the potential for enduring effects from the SAT intervention. Our exploratory analysis revealed potential additional benefits associated with a higher "dosage", in terms of practice time, in all three areas. This finding was based on the results of the compliant participants who, based on their diaries, dedicated more time and effort into practising the SAT protocol.

Additionally, our exploratory analysis examining avatar and photo utilisation provided insights for future research. Participants who utilised a combination of avatars and photos demonstrated greater and more enduring effects compared to those who solely utilised their photos. This initial observation suggests that avatars may offer supplementary benefits; however, we acknowledge the fact that many factors may contribute to the decision of the participants to use avatar or photos and therefore further rigorous testing is necessary to confirm this notion. Furthermore, one needs to investigate the impact of the VR app compared to a standard app to see if the benefits are indeed due to the immersive nature of VR.

The spontaneous experience questionnaire, as previously indicated, was an unplanned qualitative indicator, not initially incorporated into the study's design. It was a self-report measure that was thus not amenable to quantitative analysis. We have presented the aggregated findings from the questionnaire, offering some valuable insights. The majority of participants reported spontaneous recollections of their photo or avatar at least once a week, with these recollections frequently resulting in a positive emotional shift. This potentially suggests that the SAT could have a positive impact on individuals even beyond the intervention period, possibly by facilitating access to positive self-referent memories. Given that SAT aims to enable the repeated retrieval of specific hedonic memories, it is plausible to suggest that the procedure could potentiate access to more positive autobiographical memories (Köhler et al., 2015). This has the potential to target a core cognitive process in depression and other conditions where negative affect prevails. These unexpected outcomes present an opportunity to structure a study that could validate these findings.

The results of this study demonstrate the potential effectiveness of SAT in a normal population with a wide age range. The greater improvement across all measures when participants used the new technological tools (the VR app and personalised avatar) as opposed to more traditional methods (childhood photos) can be explained by the dynamic nature of virtual avatars, which can be animated to all basic emotions and made to dance with the user's favourite song, compared to static photos. The improvement in the primary and secondary outcomes were also maintained for 3 months after the completion of the intervention, which can be attributed to the development of positive habits among the participants following the intervention. Such long-term positive effects are crucial in psychotherapy, where it is common for improvements to deteriorate over time following an intervention.

The findings of our study are in line with existing research on the use of VR in psychotherapy. They indicate that exposing individuals to simulated situations through VR can yield beneficial outcomes. The prevalent form of VR in psychotherapy, namely VR exposure therapy, exploits the illusionary senses of presence, social presence, co-presence and plausibility (Freeman et al., 2017). However, for nearly 2 decades, more radical forms of VR intervention for psychotherapy have been envisaged. Riva and colleagues have envisioned that the future prospect of VR in psychotherapy could include exploring the concept of personal identity: "This means that VR could be used for experiencing another identity (real or fantastic) and for experiencing other shapes, figures, objects, and even other forms of self, as well" (Riva, 2005). With advances in VR technology, virtual body embodiment into another individual has been the underlying basis for the Proteus effect (Ratan et al., 2020) as employed in several studies: for improving cognitive task performance (Banakou et al., 2018), reducing self-criticism (Falconer et al., 2014), treating depression (Falconer et al., 2016), enhancing positive self-dialogue (Osimo et al., 2015), changing self-representation Yee et al. (2009); Kocur et al. (2021), reducing social anxiety (Emmelkamp et al., 2020) and reward training for anhedonia (Chen et al., 2021).

VR has provided the opportunity to simulate the illusion of impossible events, such as going back in time to intervene in a situation with a view to changing history in the simulated environment (Friedman et al., 2014). This experience of "epistemic expansion" can be used in psychotherapy to enable reprocessing of traumatic life events. VR allows experiencing the "other-than-self" and, by doing so, exploring new means of epistemic expansion. This other-than-self encompasses a broad spectrum of transformative possibilities, which include what it is like to be another version of self, or a possible future or past self. Riva and colleagues have argued that VR, as an advanced imaginal medium, can also be a vehicle for change in individuals, stipulating three requirements: i) self-reflectiveness by the participant, giving them the opportunity to relive and reorganise their experiences and conflicts; ii) self-efficacy in the participants, by believing they are able to change themselves; and iii) transformative experiences through which the participants acquire sudden insights to challenge and thus eventually change some of their basic beliefs and habits (Riva et al., 2016).

We can argue, based on our findings, that the user's experience of the VR-based SAT protocol to interact with their childhood avatar from a third-person perspective, incorporates elements of an "unreality simulator", "advanced imaginal system", "epistemic expansion" and illusions of "impossible events". The transformative potential of this protocol is further supported by several participant feedback. One participant wrote "Amazing course, I truly saw it as a transformative experience" while the

another commented, "The whole process had a really profound effect on me. I have found the course really transformational." A third one wrote: "Your study will have a transformative influence on the evolution of modern human cognition."

The hypothesis that the use of VR in administering SAT can be more effective than traditional methods, and even lead to transformative changes, can now be evaluated through further research studies. This resonates with an emergent focus on "transdiagnostic" or core processes in psychotherapies such as Process Based Therapy (PBT) (Hofmann and Hayes, 2018). In this regard, a core component process of SAT could be the fostering of self-referent hedonic experience, and consequential increases in prosocial and reward seeking behaviours. This conjecture is consistent with recent clinical trial findings by Craske and colleagues that promoting the pursuit of rewards and amplifying the resulting hedonic experience can be more effective than conventional psychotherapy in promoting positive affect as well as reducing both negative affect and suicidal ideation in clinically anxious and depressed people (Craske et al., 2019).

Evidence-based psychotherapy interventions which can be self-administered using VR may also help to resolve universal supply side challenges in training and staffing a workforce for psychological interventions (Pot-Kolder et al., 2020; Hatta et al., 2022). Given the low cost of administering VR at scale, compared to in-person psychology services, this may also help improve health accessibility and equity challenges at a global scale. Consistent with these challenging tasks, a chatbot has been developed to coach the user in practising SAT (Alazraki et al., 2021); and efforts are also made to produce this virtual coach in a multi-language setting (Law et al., 2022).

The main limitations of our proof-of-concept study were the small sample size and the absence of a control group. Despite this, we found significant results due to the large effect sizes observed. Since SAT is an attachment-informed intervention, another limitation is that—since we did not expect attachment styles to change in eight weeks—we had not included an attachment-based measure as a baseline demographic data point. Another limitation was the use of self-reported measures, which can be subject to bias since participants may have been inclined to provide socially desirable responses rather than accurate ones. Finally, our study only included a non-clinical population. It is crucial to replicate our findings in a clinical sample to determine the generalisability of the results.

From a psychological viewpoint, SAT can be described in the context of the Dynamic Maturational Model (DMM) of attachment and adaptation, as formulated by Patricia Crittenden (Crittenden and Landini, 2011; Crittenden, 2013). According to DMM, early attachment creates a pathway for personality development across the lifespan. A person's attachment strategy may change in response to maturation and development, as well as exposure to real or perceived danger. DMM proposes twenty-two basic attachment types which expand and build on the three-pattern model of early attachment, as originally categorised by Ainsworth: secure attachment, insecure anxious attachment and insecure avoidant attachment. In addition, according to DMM, an adult person can earn secure attachment with a romantic partner, friend, mentor, or psychotherapist as a secure base. This novel idea is called a "reorganisation" strategy, which is crucially envisaged to require a close relationship with another person to succeed. SAT proposes that in many cases, an adult person can begin and accelerate a reorganisation strategy on their own by practising exercises that emulate healthy parent/child interactions and turn the adult self of the person into a secure base.

The intervention has been hypothesised to be holistic, thus potentially beneficial to diverse clinical populations, as it aims to develop a secure attachment object, namely oneself, for the individual (Edalat, 2017). In fact, as reported in (Edalat et al., 2022), there is anecdotal evidence that SAT can help with childhood trauma as well as Obsessive Compulsive Disorder (OCD). Further development and experimentation with virtual environments and avatars should also be conducted in order to improve the quality of avatars that are created from poor quality childhood photos, which could increase the number of participants who prefer to use their avatars. The outcomes of this study provide a tentative but promising foundation for further exploration in the field, specifically on the potential benefits of VR-based SAT for clinical populations.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Science Engineering Technology Research Ethics Committee at Imperial College London (ICREC/SETREC reference number 21IC7351). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AE: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing–original draft, Writing–review and editing. NP: Data curation, Formal Analysis, Investigation, Software, Visualization, Writing–original draft, Writing–review and editing. FR: Methodology, Validation, Writing–review and editing. BG: Methodology, Validation, Writing–review and editing. DN: Methodology, Validation, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frvir.2024.1424217/full#supplementary-material

References

Ainsworth, M. D. S., Blehar, M. C., Waters, E., and Wall, S. N. (2015). *Patterns of attachment: a psychological study of the strange situation*. New York: Psychology Press. doi:10.4324/9780203758045

Alazraki, L., Ghachem, A., Polydorou, N., Khosmood, F., and Edalat, A. (2021). "An empathetic AI coach for self-attachment therapy," in 2021 IEEE third international conference on cognitive machine intelligence (CogMI), Atlanta, GA, 13–15 December 2021, (IEEE) 78–87. doi:10.1109/cogmi52975.2021.00019

Banakou, D., Kishore, S., and Slater, M. (2018). Virtually being Einstein results in an improvement in cognitive task performance and a decrease in age bias. *Front. Psychol.* 9, 917. doi:10.3389/fpsyg.2018.00917

Bowlby, E. J. M. (2008). *Attachment: volume one of the attachment and loss trilogy*. Random House.

Bowlby, J. (1973). "Attachment and loss: volume ii: separation, anxiety and anger," in *Attachment and loss: volume II: separation, anxiety and anger* (London: The Hogarth press and the institute of psycho-analysis), 1–429.

Bowlby, J. (1998) *Attachment and loss: sadness and depression*, 3. New York: Random House.

Brown, P., Waite, F., Lambe, S., Jones, J., Jenner, L., Diamond, R., et al. (2022). Automated virtual reality cognitive therapy (gameChange) in inpatient psychiatric wards: qualitative study of staff and patient views using an implementation framework. *JMIR Form. Res.* 6, e34225. doi:10.2196/34225

Butler, J., and Kern, M. L. (2016). The PERMA-Profiler: a brief multidimensional measure of flourishing. *Int. J. Wellbeing* 6, 1–48. doi:10.5502/ijw.v6i3.526

Chen, K., Barnes-Horowitz, N., Treanor, M., Sun, M., Young, K. S., and Craske, M. G. (2021). Virtual reality reward training for anhedonia: a pilot study. *Front. Psychol.* 11, 613617. doi:10.3389/fpsyg.2020.613617

Cittern, D., and Edalat, A. (2017). A neural model of empathic states in attachment-based psychotherapy. *Comput. Psychiatry* 1, 132. doi:10.1162/CPSY_a_00006

Cittern, D., Edalat, A., and Ghaznavi, I. (2017). A neural model of empathic states in attachment-based psychotherapy. In *Comput. Psychiatr Artif. Intell. Simul. Behav. (AISB)*, 1, 132, 167. doi:10.1162/CPSY_a_00006

Craig, T. K., Rus-Calafell, M., Ward, T., Leff, J. P., Huckvale, M., Howarth, E., et al. (2018). Avatar therapy for auditory verbal hallucinations in people with psychosis: a single-blind, randomised controlled trial. *Lancet Psychiatry* 5, 31–40. doi:10.1016/S2215-0366(17)30427-3

Craske, M. G., Treanor, M., Dour, H., Meuret, A., Ritz, T., and Rosenfield, D. (2019). Positive affect treatment for depression and anxiety: a randomized clinical trial for a core feature of anhedonia. *J. Consult. Clin. Psychol.* 87, 457–471. doi:10.1037/CCP0000396

Crittenden, P. M. (2013). "Attachment and psychopathology," in *Attachment theory* (Routledge), 379–418.

Crittenden, P. M., and Landini, A. (2011). *Assessing adult attachment: a dynamic-maturational approach to discourse analysis*. WW Norton & Company.

D'Cunha, N. M., Nguyen, D., Naumovski, N., McKune, A. J., Kellett, J., Georgousopoulou, E. N., et al. (2019). A mini-review of virtual reality-based interventions to promote well-being for people living with dementia and mild cognitive impairment. *Gerontology* 65, 430–440. doi:10.1159/000500040

Difede, J., Rothbaum, B. O., Rizzo, A. A., Wyka, K., Spielman, L., Reist, C., et al. (2022). Enhancing exposure therapy for posttraumatic stress disorder (PTSD): a randomized clinical trial of virtual reality and imaginal exposure with a cognitive enhancer. *Transl. psychiatry* 12, 299–9. doi:10.1038/s41398-022-02066-x

Dudasova, L., Prochazka, J., Vaculik, M., and Lorenz, T. (2021). Measuring psychological capital: revision of the Compound psychological capital scale (CPC-12). *PLOS ONE* 16, e0247114–e0247117. doi:10.1371/journal.pone.0247114

Edalat, A. (2015). "Introduction to self-attachment and its neural basis," in 2015 international joint conference on neural networks (IJCNN), Killarney, Ireland, 12-17 July 2015 (IEEE), 1–8. doi:10.1109/IJCNN.2015.7280780

Edalat, A. (2017). "Self-attachment: a holistic approach to computational psychiatry," in *Computational neurology and psychiatry* (Springer), 273–314. doi:10.1007/978-3-319-49959-8_10

Edalat, A., Farsinezhad, M., Bokharaei, M., and Judy, F. (2022). A pilot study to evaluate the efficacy of self-attachment to treat chronic anxiety and/or depression in Iranian women. *Int. J. Environ. Res. Public Health* 19, 6376. Special Issue Attachment and Mental Health. doi:10.3390/ijerph19116376

Edalat, A., Polydorou, N., Ryan, F., Gilbert, B. J., and Nicholls, D. (2023). Proof of concept for efficacy of VR-based self-attachment intervention in a non-clinical population. doi:10.31234/osf.io/wqzfx

Emmelkamp, P. M., Meyerbröker, K., and Morina, N. (2020). Virtual reality therapy in social anxiety disorder. *Curr. psychiatry Rep.* 22, 32–39. doi:10.1007/s11920-020-01156-1

Falconer, C. J., Rovira, A., King, J. A., Gilbert, P., Antley, A., Fearon, P., et al. (2016). Embodying self-compassion within virtual reality and its effects on patients with depression. *BJPsych open* 2, 74–80. doi:10.1192/bjpo.bp.115.002147

Falconer, C. J., Slater, M., Rovira, A., King, J. A., Gilbert, P., Antley, A., et al. (2014). Embodying compassion: a virtual reality paradigm for overcoming excessive self-criticism. *PloS one* 9, e111933. doi:10.1371/journal.pone.0111933

Freeman, D., Lambe, S., Kabir, T., Petit, A., Rosebrock, L., Yu, L.-M., et al. (2022). Automated virtual reality therapy to treat agoraphobic avoidance and distress in patients with psychosis (gameChange): a multicentre, parallel-group, single-blind, randomised, controlled trial in england with mediation and moderation analyses. *Lancet Psychiatry* 9, 375–388. doi:10.1016/S2215-0366(22)00060-8

Freeman, D., Reeve, S., Robinson, A., Ehlers, A., Clark, D., Spanlang, B., et al. (2017). Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychol. Med.* 47, 2393–2400. doi:10.1017/S003329171700040X

Friedman, D., Pizarro, R., Or-Berkers, K., Neyret, S., Pan, X., and Slater, M. (2014). A method for generating an illusion of backwards time travel using immersive virtual reality-an exploratory study. *Front. Psychol.* 5, 943. doi:10.3389/fpsyg.2014.00943

Garety, P., Edwards, C., Ward, T., Emsley, R., Huckvale, M., Mccrone, P., et al. (2021). Optimising AVATAR therapy for people who hear distressing voices: study protocol for the AVATAR2 multi-centre randomised controlled trial. *Trials* 22, 366. doi:10.1186/s13063-021-05301-w

Ghaznavi, I., Gillies, D., Nicholls, D., and Edalat, A. (2020). "Photorealistic avatars to enhance the efficacy of self-attachment psychotherapy," in 2020 IEEE international conference on artificial intelligence and virtual reality (AIVR), Utrecht, Netherlands, 14-18 December 2020 (IEEE), 60–67. doi:10.1109/AIVR50618.2020.00022

Ghaznavi, I., Jehanzeb, U., Edalat, A., and Gillies, D. (2019) "Usability evaluation of an immersive virtual reality platform for self-attachment psychotherapy," in *Proceedings of the 2019 CHI conference on human factors in computing systems*, 1. ACM.

Gu, J., Baer, R., Cavanagh, K., Kuyken, W., and Strauss, C. (2020). Development and psychometric properties of the sussex-oxford compassion scales (SOCS). *Assessment* 27, 3–20. doi:10.1177/1073191119860911

Hatta, M. H., Sidi, H., Sharip, S., Das, S., and Saini, S. M. (2022). The role of virtual reality as a psychological intervention for mental health disturbances during the COVID-19 pandemic: a narrative review. *Int. J. Environ. Res. Public Health* 19, 2390. doi:10.3390/IJERPH19042390

Hofmann, S. G., and Hayes, S. C. (2018). The future of intervention science: process-based therapy. *Clin. Psychol. Sci.* 7, 37–50. doi:10.1177/2167702618772296

Kerby, D. S. (2014). The simple difference formula: an approach to teaching nonparametric correlation. *Compr. Psychol.* 3 (11). IT.3.1. doi:10.2466/11.IT.3.1

Kocur, M., Habler, F., Schwind, V., Woźniak, P. W., Wolff, C., and Henze, N. (2021). "Physiological and perceptual responses to athletic avatars while cycling in virtual reality," in *Research Article*. 1–18. doi:10.1145/3411764.3445160

Köhler, C. A., Carvalho, A. F., Alves, G. S., McIntyre, R. S., Hyphantis, T. N., and Cammarota, M. (2015). Autobiographical memory disturbances in depression: a novel therapeutic target? *Neural Plast.* 2015, 1–14. doi:10.1155/2015/759139

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front. Psychol.* 4, 863. doi:10.3389/fpsyg.2013.00863

Law, A. J., Hu, R., Alazraki, L., Gopalan, A., Polydorou, N., and Edalat, A. (2022) "A multilingual virtual guide for self-attachment technique," in 2022 IEEE fourth international conference on cognitive machine intelligence CogMI 2022. Atlanta, GA, USA. doi:10.1109/CogMI56440.2022.00025

Negeri, Z. F., Levis, B., Sun, Y., He, C., Krishnan, A., Wu, Y., et al. (2021). Accuracy of the Patient Health Questionnaire-9 for screening to detect major depression: updated systematic review and individual participant data meta-analysis. *bmj* 375, n2183. doi:10.1136/bmj.n2183

O'Brien, C., Rus-Calafell, M., Craig, T. K., Garety, P., Ward, T., Lister, R., et al. (2021). Relating behaviours and therapeutic actions during AVATAR therapy dialogue: an observational study. *Br. J. Clin. Psychol.* 60, 443–462. doi:10.1111/bjc.12296

Osimo, S. A., Pizarro, R., Spanlang, B., and Slater, M. (2015). Conversations between self and self as Sigmund Freud—a virtual body ownership paradigm for self counselling. *Sci. Rep.* 5, 13899–13914. doi:10.1038/srep13899

Plummer, F., Manea, L., Trepel, D., and McMillan, D. (2016). Screening for anxiety disorders with the GAD-7 and GAD-2: a systematic review and diagnostic metaanalysis. *General Hosp. psychiatry* 39, 24–31. doi:10.1016/j.genhosppsych.2015.11.005

Polydorou, N., and Edalat, A. (2021). An interactive VR platform with emotion recognition for self-attachment intervention. *EAI Endorsed Trans. Pervasive Health Technol.* 7, 170951. doi:10.4108/eai.14-9-2021.170951

Pot-Kolder, R., Veling, W., Geraets, C., Lokkerbol, J., Smit, F., Jongeneel, A., et al. (2020). Cost-effectiveness of virtual reality cognitive behavioral therapy for psychosis: health-economic evaluation within a randomized controlled trial. *J. Med. Internet Res.* 22, e17098. doi:10.2196/17098

Powers, M. B., and Emmelkamp, P. M. (2008). Virtual reality exposure therapy for anxiety disorders: a meta-analysis. *J. anxiety Disord.* 22, 561–569. doi:10.1016/j.janxdis.2007.04.006

Ratan, R., Beyea, D., Li, B. J., and Graciano, L. (2020). Avatar characteristics induce users' behavioral conformity with small-to-medium effect sizes: a meta-analysis of the proteus effect. *Media Psychol.* 23, 651–675. doi:10.1080/15213269.2019.1623698

Riva, G. (2005). Virtual reality in psychotherapy: review. *Cyberpsychology & Behav.* 8, 220–230. doi:10.1089/cpb.2005.8.220

Riva, G., Baños, R. M., Botella, C., Mantovani, F., and Gaggioli, A. (2016). Transforming experience: the potential of augmented reality and virtual reality for enhancing personal and clinical change. *Front. psychiatry* 7, 164. doi:10.3389/fpsyt.2016.00164

Rus-Calafell, M., Ehrbar, N., Ward, T., Edwards, C., Huckvale, M., Walke, J., et al. (2022). Participants' experiences of AVATAR therapy for distressing voices: a thematic qualitative evaluation. *BMC Psychiatry* 22, 356–462. doi:10.1186/s12888-022-04010-1

Slater, M., and Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Front. Robotics AI* 3, 74. doi:10.3389/frobt.2016.00074

Winnicott, W. D. (1953). Transitional objects and transitional phenomena—a study of the first not-me possession. *Int. J. psycho-analysis* 34, 89–97.

Yee, N., Bailenson, J. N., and Ducheneaut, N. (2009). The proteus effect: implications of transformed digital self-representation on online and offline behavior. *Commun. Res.* 36, 285–312. doi:10.1177/0093650208330254