Proof of Concept for Efficacy of VR-based Self-Attachment Intervention in a Non-Clinical Population

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ABSTRACT

The aim of this proof-of-concept study was to evaluate the efficacy of a new VR platform for practising the Self-Attachment Technique (SAT) in a non-clinical population. 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. During an 8-week trial, participants practised the SAT exercises either by animating their personalised childhood avatar into different emotional states in VR or 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 well-being, self-compassion and psychological capital, are significant. Overall, participants experienced significant improvement in wellbeing (primary outcome) with large effect size ($r = 0.86$). A main result of the study indicated that the effect of VR ($d = 1.12$) is much better compared to the childhood photos ($d = 0.47$) and that the intervention had a profound impact on participants' daily lives based on their feedback. This study shows that practising SAT with the use of the participant's childhood avatar in a virtual environment can be beneficial and have enduring effects.

Introduction

The Self-Attachment Technique (SAT)[1–3] is a relatively new psychological intervention informed by attachment theory, as introduced by John Bowlby and Mary Ainsworth[4–7]. 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[8] 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.

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[9,10]. According to DMM, early attachment only 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.

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[11]. Thirty women who had had clinical depression and/or anxiety for at least three 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[12,13]. The change in anxiety level between pre-test and post-test was significant with effect size of 2.5. The change in anxiety between pre-test and follow-up test had an 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 effect sizes of 2.3 and 3.1 respectively.

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.

The role-playing by the adult consists of externalising one's negative emotions to one's childhood photo, imaginatively embracing the child, reassuring them out loud, and giving oneself a head or neck self-massage (a close counterpart for cuddling a real child in distress). There are also other self-administered exercises in SAT that mimic the actions of a primary caregiver, based on singing, dancing, playing, laughing and developing an attachment to nature in order to maximise positive affects.

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. The use of VR for the SAT protocol was first envisaged by Cittern et al.[14]. The emergence of VR technology in the past two decades has significantly enhanced many areas of human activities including psychological interventions[15]. Its huge potential to treat some mental illness and strengthen wellbeing has been investigated by many research groups across the globe[16–18]. 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[19–21]. The results have been so promising that a recent VR implementation in the treatment of phobias and psychosis has been named "gameChange" by the researching team[19,20].

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"[15] and an "advanced imaginal system"[22]. Jaron Lanier, an early researcher in the applications of VR, has described the magic of VR as akin to the world of freedom that children imagine before they inevitably accept the limitations of the real world:

> The thing that I think is so exciting about virtual reality is that it gives us this freedom again. It gives us this sense of being able to be who we are without limitation; for our imagination to become objective and shared with other people[23] (cited by Slater et. al.[15]).

The prevalent form of VR in psychotherapy, namely VR exposure therapy, exploits the illusionary senses of presence, social presence, co-presence and plausibility[18]. However, for nearly two 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."[24] With advances in VR technology, virtual body embodiment into another individual has been the underlying basis for the Proteus effect[25] as employed in several studies: for improving cognitive task performance[26], reducing self-criticism[27], treating depression[28], enhancing positive self-dialogue[29], reducing social anxiety[30] and reward training for anhedonia[31]. VR has also 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[32]. 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 [22].

The VR-based SAT protocol was considered with a basic framework designed using Oculus Rift and Avatar SDK to generate the photorealistic 3D head for the child avatar[14,33]. The VR environment allowed the user to navigate, approach and embrace their childhood avatar and was evaluated in the non-clinical population: 10 volunteers, in their twenties, had five minutes to familiarise themselves with the VR platform and its controls, and then took part in a 30-45 minute session to interact with their childhood avatar. Participants were asked about the effectiveness of the avatar in comparison with their childhood photo: the average rating on a five-point Likert scale was 4.25. 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. Fifteen volunteers, mostly in their twenties, were

recruited from the non-clinical population to engage with the VR using their mobile phones for a week. Nearly 85% of the participants (N=13) reported their avatar in mobile VR to be more relatable than their ordinary childhood pictures[34].

In the next experiment, a comparison was made between participants interacting with a generic child avatar versus their own childhood avatar. This work was 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[27,28]. A high-end version of the VR environment, equipped with an AI agent, a dialogue manager and a platform for audio and text detection of the user's emotion was constructed and evaluated during the pandemic[35]. 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-minute sessions separated by seven to ten 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.

The outcome of these experiments, which only focused on evaluating the use of the low-end and high-end VR platforms, led us to undertake an 8-week VR-based human trial for the SAT protocol in a non-clinical population. Our hypothesis is that the use of childhood avatars and VR, in practising the SAT protocol, provides a more effective way of inducing change in the individual in the primary area of wellbeing and the secondary areas of self-compassion and psychological capital, compared to the use of mental imagery or photos. We have also been interested to determine if interaction with one's childhood avatar can lead to transformative self-change, a paradigm envisioned in Riva's paper on VR in psychotherapy[24].

Methods

Study design

We designed a single factor, within-subject experiment. Before the start of the intervention participants were required to watch the videos of two online workshops that introduced them to the study and SAT theory. Participants learned how to practice the SAT exercises in eight weekly online Zoom group sessions of 90 minutes each. In these sessions, the participants first voluntarily shared their experiences in practising the exercises of the previous week. Then, the exercises for the following week were presented to them and finally, they had the chance to ask questions regarding the protocol.

Participants were expected to individually practice the exercises for at least 15 minutes twice a day throughout the eight weeks of the intervention and complete a personal diary daily. Participants were asked to complete three standard self-rating questionnaires (PERMA-Profiler, SOCS-S, CPC-12R) through the Qualtrics platform on three occasions: before the intervention (pre-test), following completion after eight weeks (post-test), and in a 3-month follow-up (follow-up test).

The primary outcome measure of the study was considered to be wellbeing as rated using the PERMA-Profiler questionnaire. 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[36].

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[37]. For psychological capital, we employed the Compound Psychological Capital Scale (CPC-12R), which measures hope, self-efficacy, resilience, and optimism with adequate psychometric properties[38].

Also, we sought to find out whether, during the 3-month period following the completion of the 8-week intervention, participants experienced any spontaneous recall of the image of their childhood photo or avatar. Participants completed a questionnaire in which they were asked to indicate whether this 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 the persistence of the effects of the intervention as demonstrated by the primary and secondary outcomes of the study.

Participants

We recruited volunteers from the non-clinical population who were screened using GAD-7, PHQ-9 and WEMWBS scales. We included volunteers fluent in English between ages 20 and 65 from Europe or North America.

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 $p < 0.05$, 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 in week 3 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.

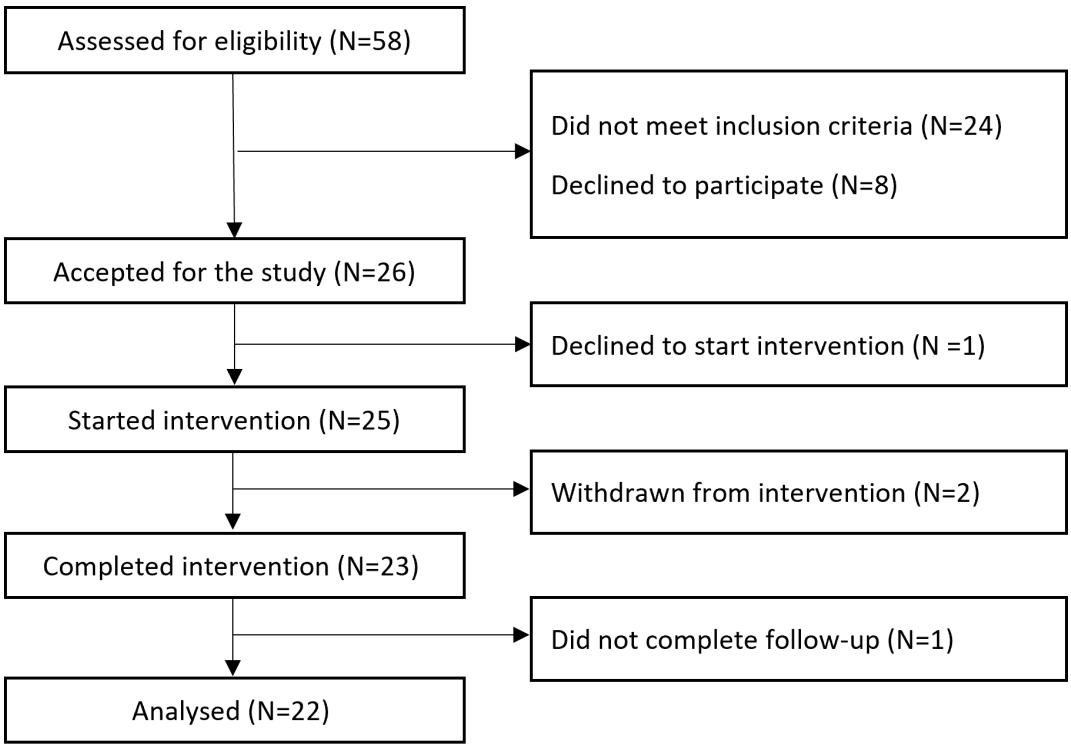

Figure 1. Consort diagram.

VR protocol

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. The virtual environment (VE) included personalised features for each user as well as common features for all users. The most important items were a personalised look-alike child avatar that was created from the favourite childhood photo of the user based on Avatar SDK, together with the favourite happy song of the user that could be played in the VE. 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. Another key 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 thirty seconds. By further staring for another thirty seconds, the avatar would start to dance to the user's favourite song.

Since the average age (41.6) of the participants was significantly higher than those in the previous studies, we had anticipated that many participants would not have good quality childhood photos. We allowed participants to choose whether to use their childhood photos or their avatar. Out of the 22 participants, 11 were able to identify with their avatars and 11 decided to use their childhood photos. With these two avatar and photo subgroups of equal size, a comparison can be made in order to understand differences in the efficacy of the protocol.

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 (Likert scale 1 to 5) their agreement with the statements that the mobile app was easy to use and the environment was effectively interactive.

SAT protocol

The SAT protocol, as a double role-playing game, is self-administered in the following way: 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. A detailed description of the core protocol is as follows.

1. Look at their most and least favourite childhood photos and the childhood avatar with different emotions and use their power of imagination to interact with their childhood self.

2. Establish a compassionate connection with their childhood self by focusing attention on their photos and their avatar animated with basic emotions (happy, sad, angry, fearful, disgusted, surprised).

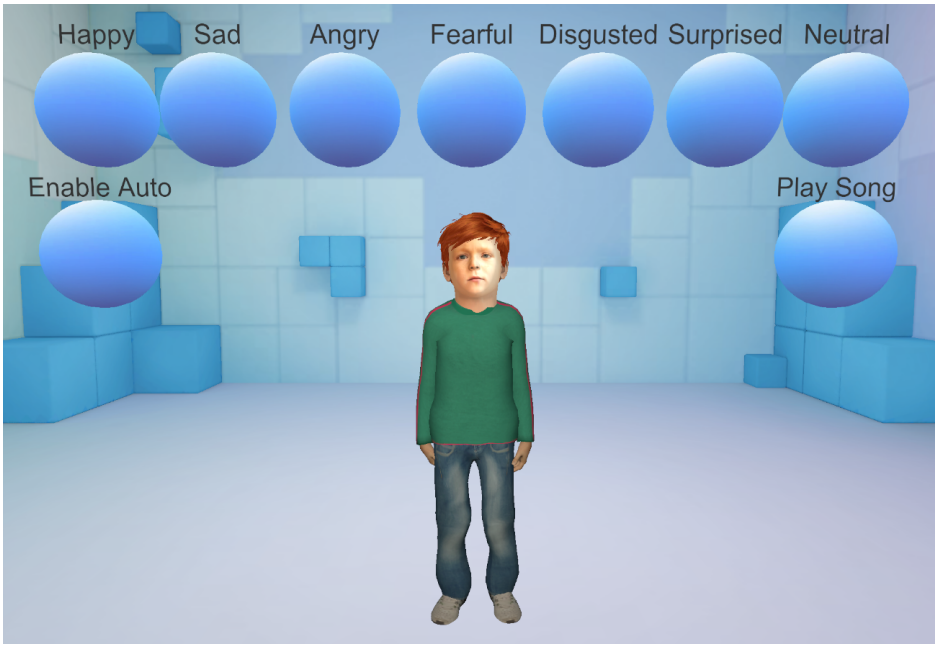

Figure 2. Virtual Environment with customised child avatar and emotion selections.

3. Use their favourite song, that expresses compassion and affection for the childhood self, by repeatedly reciting it while looking at their favourite photo and the happy avatar, in order to create a passionate and loving bond with their childhood self.
4. Commit to re-raise the childhood self to enhanced social and emotional maturity.
5. Project their positive and negative emotions, respectively, onto their photos and on their correspondingly animated avatar.
6. Maximise the positive emotions projected onto the favourite photo and the happy avatar through singing, dancing and laughter.
7. Minimise any negative emotions projected onto the non-favourite photo and the animated avatar by self-hug, head-neck massage, verbal assurance and affirmations, while imagining these actions are performed on the childhood self.

Figure 3. Basic emotions (happy, sad, angry, fearful, disgusted, surprised, neutral) displayed on avatar.

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 (https://pingouin-stats.org/) and researchpy 0.3.5 (https://researchpy.readthedocs.io/).

We used paired t-tests for each comparison to investigate whether effects over time were statistically significant ($p < 0.05$). Due to the normality assumption, we used the Shapiro–Wilk test to check whether the difference between the paired samples

Figure 4. Avatar dance animation.

was normally distributed. In case normality was not satisfied, we used Wilcoxon signed-rank test to prove the significance of the results ($p < 0.05$).

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[39]. 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

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

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)[40] 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.

Group analysis

We investigated the data from 22 participants as a whole group as well as data from three subgroups. In terms of the requirement for the participants to practice the SAT exercises and write a short summary in their diary, 18 out of 22 participants filled out more than 60% of their diary and 4 out of 22 filled out less than 40%. By observing the participants' diaries, we found that 11 participants used only their photos to practice SAT exercises whereas the others preferred to use their personalised avatar. We therefore analysed the data for the following groups:

- Whole group (N=22): Includes all participants who completed the 3 measurements (pre-test, post-test and follow-up test).
- Compliant subgroup (N=18): Includes participants who completed more than 40% of their diaries.
- Avatar subgroup (N=11): Includes participants who practised SAT exercises with their child avatar.
- Photo subgroup (N=11): Includes participants who practised SAT exercises with their childhood photos only.

We were interested to understand whether participants in the Compliant subgroup had greater effects than those in the Whole group and whether the Avatar subgroup experienced more positive effects compared to the Photo subgroup.

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.

Results

The results for all four groups (the Whole group as well as the Compliant, Avatar and Photo subgroups) are presented for each of the outcomes (PERMA, SOCS-S, CPC-12R). Despite the significant time commitment (at least 30-minutes practice required daily for 8 weeks and weekly group sessions lasting 90 minutes each), the dropout rate was low (12%).

Primary outcome: PERMA

The results for the primary outcome can be found in Table 1. Recall that we used the Cohen's d for effect size when normality was satisfied and the rank-biserial correlation r when it was not satisfied.

For the Whole group, the analysis showed significant improvement in PERMA scores between pre-test ($median = 6.78$) and post-test ($median = 7.94$) with large effect size, $Z = 3.38$, $p = 0.001$, $r = 0.86$. 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, $t(21) = 3.42$, $p = 0.003$, $d = 0.75$.

The result of the Compliant subgroup was significant between pre-test ($median = 6.66$) and post-test ($median = 8.06$) with large effect size, $Z = 3.34$, $p = 0.001$, $r = 0.92$. The expectation of better results in the Compliant subgroup was also confirmed between pre-test ($mean = 6.66$, $std = 1.18$) and follow-up test ($mean = 7.70$, $std = 0.92$) that demonstrated significant improvement with large effect size, $t(17) = 3.93$, $p = 0.001$, $d = 0.98$.

The test for the Avatar subgroup 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, $t(10) = 2.9$, $p = 0.016$, $d = 1.12$ 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, $t(10) = 3.35$, $p = 0.007$, $d = 1.23$. The very large effect size ($d = 1.12$) at the end of the intervention is further increased at 3-month follow-up ($d = 1.23$).

Table 1. PERMA statistical tests (for 4 groups): 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.

PERMA	Comparison	t-value	ES (d)	Z-value	ES (r)	p-value
Whole group (N=22)	Pre/Post			3.38	0.86	0.001
	Pre/Follow-up	3.42	0.75			0.003
Compliant subgroup (N=18)	Pre/Post			3.34	0.92	0.001
	Pre/Follow-up	3.93	0.98			0.001
Avatar subgroup (N=11)	Pre/Post	2.9	1.12			0.016
	Pre/Follow-up	3.35	1.23			0.007
Photo subgroup (N=11)	Pre/Post	2.9	0.47			0.016
	Pre/Follow-up	1.52	0.41			0.159

The only significant result for the Photo subgroup 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, $t(10) = 2.9$, $p = 0.016$, $d = 0.47$. This effect size was much lower than the effect size of the Avatar subgroup ($d = 1.12$) based on direct comparison on PERMA. For the Photo subgroup the pre-test to follow-up test comparison was not significant. More results on the sub-scales of PERMA for all groups can be found in the Supplementary Material.

Secondary outcome: SOCS-S

The results for the secondary outcome (SOCS-S) can be found in Table 2. For the Whole group, there was a significant increase in self-compassion between pre-test ($median = 73.5$) and post-test ($median = 86$) with large effect size, $Z = 2.55$, $p = 0.009$, $r = 0.62$. 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, $t(21) = 3.78$, $p = 0.001$, $d = 0.78$.

The results were similar for the Compliant subgroup, with significant large effect in self-compassion scores between pre-test ($median = 73.5$) and post-test ($median = 88.5$), $Z = 2.33$, $p = 0.018$, $r = 0.63$. This large effect was also significant in scores between pre-test ($mean = 73.1$, $std = 9.2$) and follow-up test ($mean = 83.1$, $std = 9.7$), $t(17) = 5.27$, $p < 0.001$, $d = 1.03$.

The Avatar subgroup had higher effect sizes, with the test indicating significant increase in self-compassion between pre-test ($mean = 74.6$, $std = 9.1$) and post-test ($mean = 85.9$, $std = 13.8$), $t(10) = 3.05$, $p = 0.012$, $d = 0.95$ as well as between pre-test and follow-up ($mean = 85.3$, $std = 9.5$), $t(10) = 3.64$, $p = 0.005$, $d = 1.11$. The pre-test to post-test and pre-test to follow-up results were again non-significant for the Photo subgroup. More results on the sub-scales of SOCS-S for all groups can be found in the Supplementary Material.

Secondary outcome: CPC-12R

Significant results with medium to large effect sizes were observed for CPC-12R scale as shown in Table 3. The statistical test indicated similar results for the Whole group and the Compliant subgroup as the increase in psychological capital was significant with medium effect size. The results for the Whole group between pre-test ($mean = 55.6$, $std = 9.9$) and post-test ($mean = 60.8$, $std = 7.23$) were $t(21) = 3.3$, $p = 0.003$, $d = 0.59$, and for the Compliant subgroup between pre-test ($mean = 59.8$, $std = 6.79$) and post-test ($mean = 61.4$, $std = 7.26$) were $t(17) = 2.9$, $p = 0.01$, $d = 0.6$. These significant

Table 2. SOCS-S statistical tests (for 4 groups): 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.

SOCS-S	Comparison	t-value	ES (d)	Z-value	ES (r)	p-value
Whole group (N=22)	Pre/Post			2.55	0.62	0.009
	Pre/Follow-up	3.78	0.78			0.001
Compliant subgroup (N=18)	Pre/Post			2.33	0.63	0.018
	Pre/Follow-up	5.27	1.03			<0.001
Avatar subgroup (N=11)	Pre/Post	3.05	0.95			0.012
	Pre/Follow-up	3.64	1.11			0.005
Photo subgroup (N=11)	Pre/Post			1.07	0.36	0.32
	Pre/Follow-up	1.87	0.53			0.091

results were maintained at 3-month follow-up with large effect sizes for both the Whole group, $Z = 2.53$, $p = 0.012$, $r = 0.68$ and the Compliant subgroup, $Z = 2.45$, $p = 0.016$, $r = 0.72$. On the other hand, the Avatar subgroup demonstrated greater effect size than the other 2 groups between pre-test ($mean = 55,\ std = 12$) and post-test ($mean = 62.9,\ std = 6.93$), $t(10) = 2.77$, $p = 0.02$, $d = 0.79$, but medium effect size between pre-test ($mean = 55,\ std = 12$) and follow-up test ($mean = 61.6,\ std = 5.82$), $t(10) = 2.66$, $p = 0.024$, $d = 0.71$.

Table 3. CPC-12R statistical tests (for 4 groups): 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.

CPC-12R	Comparison	t-value	ES (d)	Z-value	ES (r)	p-value
Whole group (N=22)	Pre/Post	3.3	0.59			0.003
	Pre/Follow-up			2.53	0.68	0.012
Compliant subgroup (N=18)	Pre/Post	2.9	0.6			0.010
	Pre/Follow-up			2.45	0.72	0.016
Avatar subgroup (N=11)	Pre/Post	2.77	0.79			0.020
	Pre/Follow-up	2.66	0.71			0.024
Photo subgroup (N=11)	Pre/Post	2.49	0.33			0.032
	Pre/Follow-up	1.5	0.23			0.165

Similar to the primary outcome (PERMA), the Photo subgroup showed significant change in CPC-12R from pre-test to post-test. 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, $t(10) = 2.49$, $p = 0.032$, $d = 0.33$. The pre-test to follow-up test comparison was not significant for the Photo subgroup.

VR app

On the scale 1 to 7, participants in the Avatar subgroup on average felt highly proficient ($mean = 5.27,\ std = 1.66$) and felt highly immersed ($mean = 5.36,\ std = 1.77$) in the environment. The participants 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 ($mean = 4.36,\ std = 0.98$).

Spontaneous Experience

The results of the spontaneous experience questionnaire showed that among all participants (N=22), 82% (N=18) had this experience with either their avatars or photos at least once per week three months after the end of the study. 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.

Participants' Quotes

At the end of the intervention, participants were asked to provide feedback on their overall experience of the intervention. Here are some of their comments:

- "I have enjoyed the programme."
- "I could see the value of the protocol."
- "Amazing course, I truly saw it as a transformative experience."
- "It was a revealing experience, challenging but positive experience."
- "On of the key aspects of the program is that it caused me to maintain an awareness about I was feeling at any point in time."
- "The whole process had a really profound effect on me. I have found the course really transformational."
- "The whole experience is very useful to use in everyday life."

In a letter to express their appreciation, one of the participants wrote:

> "I am so convinced that the SAT practice has a remarkable meaning for everyone. SAT practice enables a person to efficiently modify one's mental state in times of depression and anger, as well as to face hardship with a positive, even transcendent, mental attitude. Imagine the potential that each individual would bring if they could use this inward restoring, adjusting power from Mother Nature to regain courage, overcome obstacles and innovate. Your study will have a transformative influence on the evolution of modern human cognition."

The effectiveness of the child avatar and its advantage over the childhood photos was also reflected in comments from participants:

> "What I liked most was the connection that has been created with my childhood self. I could not have this connection just by using the photos. In addition, I could engage more with the avatar, where I had the control over the emotions."

> "I felt attached to the avatar and emotional when hearing the song and dancing with my avatar."

Discussion

This proof-of-concept study demonstrates the feasibility and potential utility of VR technology in administering SAT. Our study has shown that SAT yields significant improvements in 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 key 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 investigation for the primary outcome measure showed significant results for all groups with positive changes in wellbeing, as measured by PERMA, that were maintained three months after the intervention. The tests showed that the effect on the Compliant subgroup was greater than the Whole group which suggests that the more time and effort is put into practising the SAT protocol, the greater the effect on wellbeing can be. Furthermore, effects on PERMA are much higher when participants used their avatar rather than just their photos to practice the exercises, and the use of avatars can have enduring effects and continue to improve wellbeing after the SAT intervention is completed. In addition, large effect sizes on the secondary measure of SOCS-S, present a first indication that VR and the customised avatars can enhance self-compassion. Significant results with medium to large effect sizes were observed for CPC-12R scale as well, which shows the potential of the SAT intervention to improve psychological capital. Again, in both secondary outcomes the higher effect in the Avatar subgroup than in the Photo subgroup further supports the benefits of the use of the avatar over photos to practice SAT.

The results of this study demonstrate the 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 (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 three 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 hypothesis that the use of VR in administering SAT can be more effective than traditional methods, and lead to transformative changes, can now be verified through further research studies. This resonates with an emergent focus on "transdiagnostic" or core processes in psychotherapies such as Process Based Therapy (PBT)[41]. 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 coworkers 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[42].

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[43,44]. 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[45]; and efforts are also made to produce this virtual coach in a multi-language setting[46].

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. 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, and the results may not be transferable to individuals with clinical conditions. It is crucial to replicate our findings in a clinical sample to determine the generalisability of the results.

The outcomes of this study provide a foundation for further exploration in the field, specifically on the potential benefits of VR-based SAT for clinical populations. 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.

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Author contributions statement

N.P. developed the software (VR application), A.E. conceptualised the SAT protocol, designed the methods and applied for ethical approval, B.G., F.R. and D.N. reviewed the protocol, A.E. and N.P. conducted the 8-week study, N.P. collected, curated and analysed the data, N.P. and A.E. analysed the results and wrote the manuscript draft, F.R., D.N. and B.G. reviewed and edited the paper, and A.E. acquired the resources (funding). All authors reviewed and agreed to the final manuscript.

Data availability

All data generated or analysed during this study are included in this published article (and its Supplementary Material files).

Additional information

The authors declare no competing interests.